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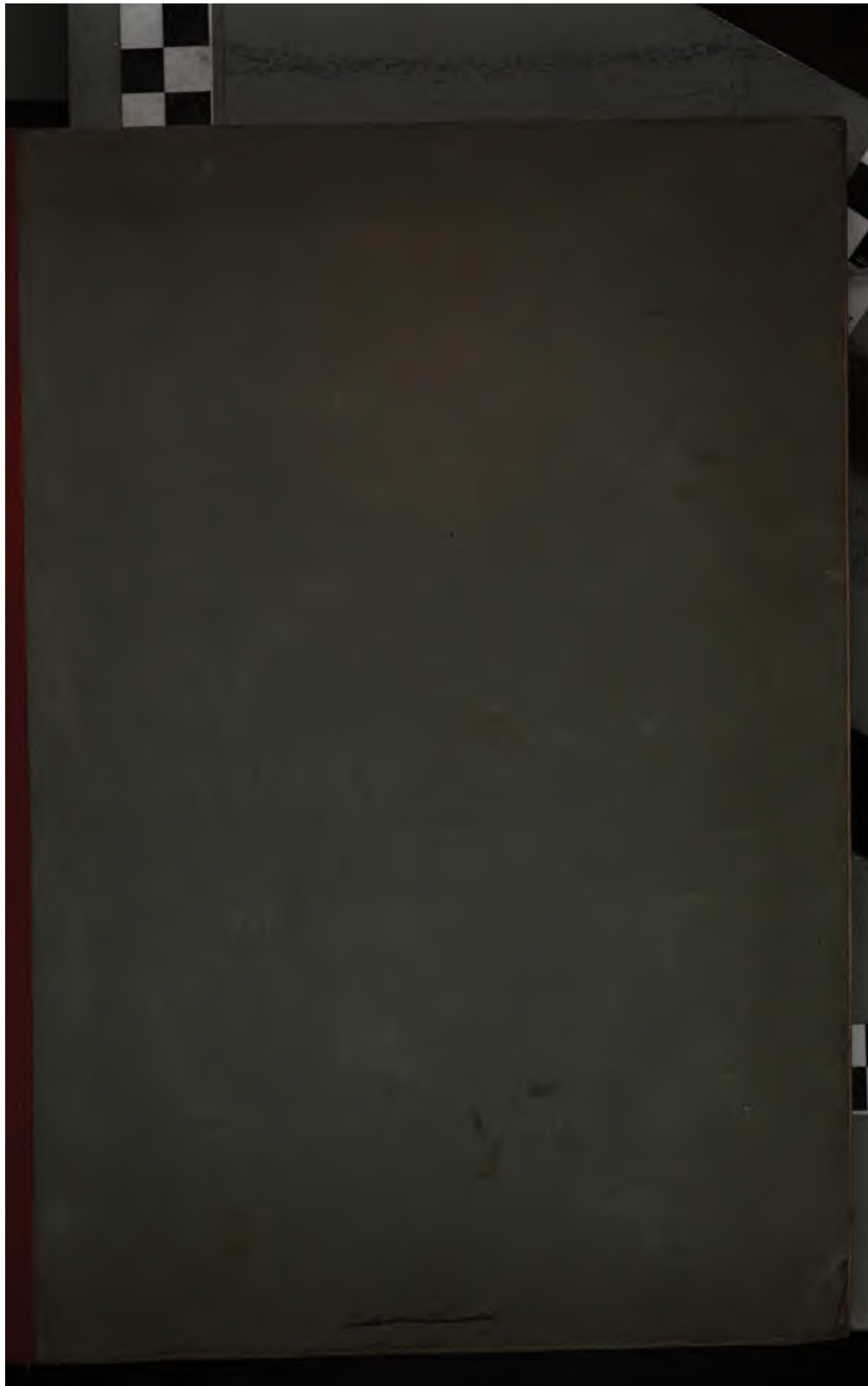
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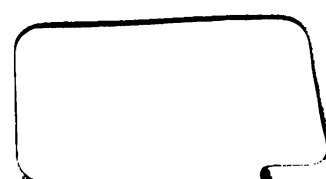
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# ELEMENTARY LECTURES

ON

## Artillery,

PREPARED FOR THE USE OF THE GENTLEMEN CADETS

OF THE

# ROYAL MILITARY ACADEMY.

---

BY

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AND

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*THIRD EDITION.*

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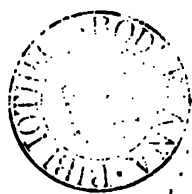
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## PREFACE.

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THE following Lectures have been prepared for the use of the Gentlemen Cadets of the Royal Military Academy, and it is hoped that they will be found of service to them after they have obtained commissions, and, in fact, to any Officer desirous of studying his profession, the subjects being systematically arranged, and containing the most important principles of Gunnery, Rifling, Construction of Ordnance, &c., with a considerable amount of detail.

These Lectures are not to be considered as treatises, but merely as “aids” to instruction, which can be expanded by the Instructor in *vivâ voce* Lectures, and supplemented by the written notes and drawings of the Cadets; they can, moreover, be corrected and enlarged when desirable to suit the various improvements in arms, &c. introduced, from time to time, a half-margin being also left for manuscript notes. It is necessary to state that they must be taken in connexion with “Boxer’s *Treatise on Gunnery and Plates of Ordnance*,” both of which are constantly referred to, the former treating of the more advanced and difficult problems in gunnery.

In reprinting these Lectures considerable additions have been made throughout, the Lectures on Gunnery and Rifled Arms re-arranged, and the greater part of them re-written, in consequence of which there are now twelve instead of eleven Lectures. Lecture XI. on the Organization, Equipment, and Application of Field Artillery has also been for the most part re-written, and the arrangement slightly altered. No plates are referred to but those at the end of the Lectures, or Boxer’s plates of guns, the former being numbered thus 1, 2, 3, 4, &c., and the latter thus I. II. III. IV. &c.; the Plates of Carriages, &c. have been drawn by measurement from the latest patterns, and tables of Ordnance, Carriages, Ammunition, and Ranges, which were omitted in the First Edition, have been here inserted.

C. H. O.

WOOLWICH,  
August, 1861.



# CONTENTS.

## LECTURE I:—

INTRODUCTORY, on the History of Artillery.—Ancient war-like machines; brief sketch of the advances made in successive centuries in artillery matériel, in gunnery as a science, and in the application of artillery in war from the present time .....	1—13
--	------

## LECTURE II:—

Construction of Guns .....	14—28
Definitions .....	14
Bore.—Windage, chambers, length of bore .....	—
Exterior Form.—General form of ordnance; amount and thickness of metal; strain increases with calibre; American experiment to ascertain amount of strain on different parts of a gun; effect of angle of elevation upon strain; strain upon rifled guns, also upon mortars; certain amount of weight necessary in a gun; swell of muzzle; unequal strain upon interior and exterior portions of a cast gun; methods of equalizing strains.....	18
Preponderance and Position of Trunnions.—Definitions; method of finding centre of gravity; amount of preponderance in service guns; French definition of preponderance and amount in their guns; trunnions, their dimensions and position; vent .....	25

## LECTURE III:—

General Description of Ordnance.....	29—38
Classification of Ordnance .....	29
Guns.—Classification of guns; bored-up guns; shell guns; shot guns; rifled guns .....	—
Mortars.—Iron mortars; bronze mortars .....	33
Howitzers.—Iron howitzers; bronze howitzers; disadvantages of combining guns and howitzers together .....	34
Carronades.—Advantages; peculiar construction .....	35
Table of Ordnance in the Service .....	36
French Guns.—Napoleon gun; rifled guns.....	37

## LECTURE IV:—

Artillery carriages .....	39—47
Classification of artillery carriages.....	39
General principles of construction of artillery carriages.—General principles to be observed in the manufacture; points to be considered with regard to the draught of a carriage .....	—
Number of horses required for artillery carriages.—Force of traction; work of a horse in draught; number of horses required according to circumstances .....	42
Mode of draught.—Shafts; pole.....	44
Effect of the discharge of a gun upon its carriage.—Effect upon the carriage when it stands on horizontal ground, and the axis of the piece is also horizontal; effect when the gun is elevated as the ground slopes; effect when axis of trunnions is below that of bore; how impulse on elevating screw is affected by the position of trunnions; principles to be observed in order to lessen the strain upon a gun-carriage .....	44

## LECTURE V:—

General description of artillery carriages .....	48—62
Field carriages.—Gun carriages, ammunition and other carriages .....	48
Carriages for position guns .....	52
Siege carriages.—Gun carriage; howitzer carriage; ground platform; Madras platform; Clerk's platform .....	53
Garrison carriages, and carriages for Coast Batteries.—Standing carriages; traversing platforms .....	56
Carriages for the transport of heavy ordnance and their carriages.—Sling cart; aling and platform wagons; trench cart .....	58
Naval gun carriages.—Ship, rear-chock, aliding, and jamming carriages; field carriages, and carriages for boat service ...	59
Mortar beds.—Wood and iron .....	61
Table of weights of carriages .....	62
ditto traversing platforms .....	—
ditto mortar beds .....	—

## LECTURE VI:—

Ammunition.....	63—84
Classification .....	63
Ammunition for ordnance.—Classification; round shot; grape; canister; common shells; Martin's shells; shrapnel shells; segment shells; carcasses; light balls; smoke balls; tables of shots and shell; fuzes; sabot, charges; wads; tubes; locks; portfires; match .....	—
Ammunition for small arms.—Classification; bullets; cartridges; caps .....	86
Rockets.—General principle; signal rockets; Congreve rockets; Hale's rockets .....	88
Compositions .....	92

## LECTURE VII:—

Gunnery .....	95—190
General Principles.—Motion in vacuo; effect of the air upon a projectile; definitions; Hutton's deductions with regard to initial velocity; formula for initial velocity of ball; Navar electro-ballistic apparatus; velocity of recoil; comparison of velocity of recoil and strain upon carriages; resistance and retardation; trajectory of a projectile in the atmosphere; formula for final velocity; formula for terminal velocity .....	95
Penetration of Projectiles.—Circumstances upon which penetration depends; formula for penetration; French and American experiments; causes of error in tables of penetration; effect of shot upon iron; penetration of elongated projectiles .....	112

## LECTURE VIII:—

Gunnery ( <i>continued</i> ) .....	121—136
Deviations of Projectiles from smooth-bored Ordnance.—causes of deviations; explanations of Robins; experiments and explanations of Magnus; deviations of eccentric shot; trajectory a curve of double curvature .....	—
The object of rifling, and considerations in connexion with its application.—Object of rifling, and manner of giving rotatory motion to a projectile; the most important con-	

## CONTENTS.

	PAGE		PAGE
considerations in rifling; elongated projectiles, effect of the air upon them, and their deviations explained with the aid of the gyroscope; principles derived from the above; cannelures; ranges of elongated projectiles; long projectiles; number, depth, and inclination of grooves; velocity of rotation; gaining twist; charge .....	126	projectile; Prussian gun and projectile; advantages of rifled guns .....	169
 <b>LECTURE IX:—</b>			
Application of Gunnery.....	137—163	<b>LECTURE XI:—</b>	
Practical gunnery classed as horizontal or vertical fire .....	137	Organization, Equipment, and Application of Artillery .....	181—212
Horizontal Fire.—Laying guns and howitzers, line and elevation; definitions and terms, calculation for graduation of tangent scale, peculiarity of Sir W. Armstrong's tangent-scale; quarter-sights; quadrants; tables of practice; elevation on inclined planes; practical rules for elevation; time of flight .....	—	General Remarks and Classification of Artillery .....	181
Different kinds of horizontal fire.—Classification; enfilade; ricochet; tables of ricochet practice; Prussian ricochet fire from field pieces; curved fire .....	145	Organization of Field Artillery.—Necessity for good organization and equipment; object of field artillery; field artillery organized in batteries; number of guns with an army; nature of ordnance required under different circumstances; number of pieces in a battery; gun, howitzer, and mixed batteries; ammunition for field service; animals employed for field artillery service .....	—
Vertical Fire.—Inaccuracy of vertical fire; probable accuracy; table of ranges; rules for practice; time of flight; angle and velocity of descent; long ranges from mortars and guns.....	149	Horse Artillery.—Purposes for which required; introduction of horse artillery; armament of horse artillery, and proportion of horse artillery to field batteries; detail of a horse artillery battery .....	187
Breaching Revetments.—Different methods; experiments at Metz and Bapaume; position and armament of breaching batteries; method of forming breach; rate of firing, amount of charge, &c.; method of breaching Carnot's wall; time and quantity of ammunition; tables; advantages of rifled pieces for breaching; experiments at Eastbourne .....	155	Field Batteries.—Purposes for which used; armament of field batteries .....	189
		Batteries of Position.—Objects for which used; armament, &c. ....	190
		Mountain Batteries.—Purposes for which employed; equipment, armament, &c. ....	192
		Application of Field Artillery.—Marches and convoys; encampments; choice of ground; position of artillery in the field; nature of fire, &c.; choice of object; movements upon the field; attack and defence of positions; passage of a river; embarkation and disembarkation of artillery; examples of the employment of artillery in different actions. 193	193
 <b>LECTURE X:—</b>			
Rifled Small Arms and Ordnance.....	164—182	<b>LECTURE XII:—</b>	
The Rifle.—Early rifled small-arms; principle of rifling explained by Robins; Baker's rifle; Delvigne's rifle with chamber; Carabine à tige; introduction of elongated projectiles; Prussian needle gun; Minié bullet; Pritchett bullet; service bullet; Whitworth's, Lancaster's, &c.; table of rifled arms successively adopted into the service; lubrication of rifle bullets .....	164	Organization, Equipment, and Application of Artillery .....	213—234
Rifled Ordnance.—Difficulties in the construction of rifled ordnance and projectiles; advantages of breech-loading ordnance; Cavalli and Wahrendorf guns and projectiles; Lancaster's system of rifling; Armstrong's guns and projectiles; Whitworth's gun and projectiles; French gun and		Siege Artillery.—Objects of siege artillery; organization; ordnance, quantity of, &c.; ordnance at Sebastopol; ammunition; tables of ammunition at Sebastopol; carriages, beds, platforms, &c.; men; depots; magazines; arming of batteries; employment of different ordnance and of different kinds of fire; captured ordnance .....	213
		Garrison Artillery.—Armament of fortresses; description and number of ordnance; quantity of ammunition; carriages, platforms, &c.; men; employment of siege artillery .....	225
		Coast Batteries.—Armament; nature of ordnance; ammunition; carriages, platforms, &c.; employment of coast artillery .....	230

## LIST OF PLATES.

Ancient Warlike Machines . . . . .	1	Bormann's and Breithaupt's Fuzes . . . . .	22
Ordnance of Early Construction . . . . .	2	Tubes . . . . .	23
Modern Ordnance (smooth-bored) . . . . .	3	Rockets . . . . .	24
Windage, Chambers, &c. . . . .	4	Parabolic Theory, &c. . . . .	25
Strain upon a Gun Carriage . . . . .	5	Trajectory of a Projectile, and Electro-Ballistic Apparatus . . . . .	26
9-pr. Field Gun Carriage . . . . .	6	Rotation of Projectiles . . . . .	27
Field Gun Carriage for 12-pr. Armstrong Gun . . . . .	7	Principle of Elevating Guns . . . . .	28
18-pr. Block Trail Carriage . . . . .	8	Calculation of Tangent Scale, and Quadrants . . . . .	29
24-pr. Siege Carriage . . . . .	9	Ricochet, Curved, and Vertical Fire . . . . .	30
10-in. Howitzer Carriage . . . . .	10	Bullets for Rifled Small Arms, and Projectiles for Rifled	
Ammunition Wagon and Siege Limber . . . . .	11	Ordnance . . . . .	31
Garrison Standing Carriage . . . . .	12	Rifled Ordnance . . . . .	32
Rear Chock Carriage . . . . .	13	Formations of a Battery or Brigade of Batteries . . . . .	33
Sling Wagon . . . . .	14	Encampment of a Battery . . . . .	34
Platform Wagon . . . . .	15	Defence of a Position, and Passage of a River . . . . .	35
10-in. Mortar Bed . . . . .	16	Passage of the Lech . . . . .	36
Dwarf, Traversing, and Madras Platforms . . . . .	17	Battle of Friedland . . . . .	37
Projectiles . . . . .	18	do Wagram . . . . .	38
do . . . . .	19	do Lutzen . . . . .	39
Shell Firing . . . . .	20	do Hanau . . . . .	40
Service Fuzes . . . . .	21		



## ERRATA.

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*For* Captain Boxer, R.A., *read* Lieut.-Colonel Boxer, R.A. throughout the Lectures.

In Art. 49, page 58, *instead of* "run up," *read* "run back (when at drill)."

In Table page 116, the penetration of 24 lb. ball with  $\frac{1}{2}$  charge at 55 yds. into masonry ought to be 23·8 in. instead of 2·38 in.

At the end of Art. 46, page 232, *read* "beaches" *for* "breaches."

## ON THE HISTORY OF ARTILLERY.

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1. THE term "artillery" was applied to all kinds of weapons before the introduction of gunpowder, but now includes only the larger descriptions of fire-arms, such as guns, mortars, howitzers, rockets, &c. Moretti, in his *Treatise* (translated by Sir Jonas Moore, about 1683) says that the word "artillery" is derived from the Italian "artiglio," signifying "the talons or claws of ravenous fowls, perhaps because its shot flying far off dismembers and tears in pieces all that it meets." This word is also said to be derived from "arcus" a bow, the earlier species of artillery being termed "arcualia." The most probable derivation appears however to be from "ars telaria," which according to Du Cange occurs first in Rymer, and signifies bows, arrows, and all implements of war.<sup>1</sup>

In the following brief sketch of the History of Artillery, after a short notice has been given of the machines used previous to the employment of fire-arms, and a few remarks made on the discovery of gunpowder and other pyrotechnical compositions, the gradual development of each of the three branches into which the subject may be divided will be pointed out; these branches are (1) Artillery Matériel, (2) the Science of Gunnery, and (3) the Application of Artillery as an arm in war.

Ancient  
engines  
of war.

2. The bow and the common sling were the first species of artillery, and the latter is still retained among the Arabs of the upper Euphrates.<sup>2</sup> The earliest account we have of the former is in Gen xxi. 20, where it is said of Ishmael, that "he dwelt in the wilderness, and became an archer;" and his successors got their living for the most part by means of this instrument. As to its inventor, the accounts are so mythological, that it would be useless to run through a list of the names of those to whom the honor has been assigned, but it seems certain, that the Scythians were among the first who extensively used this weapon. Pliny attributes the invention of the sling to the Phœnicians, but Vegetius to the inhabitants of the Balearic Isles, who were famous among the ancients for their skill in the use of it, and in whose hands it became a formidable weapon.

3. The larger engines of war known to the ancients, and used with various modifications until the adoption of cannon,

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<sup>1</sup> Fosbroke's *Encyclopædia of Antiquities*.

<sup>2</sup> Chesney, *On Fire Arms*, p. 18.

comprehended the catapulta, balista, battering-ram, &c., as well as towers of war, from which projectiles were thrown into besieged towns and fortresses. The ancient catapulta and balista are said to have been more powerful than those used in the middle ages, and were also of different construction, their forms being diversified according to place, customs, and other circumstances; the ancient balista threw beams of wood and stones sometimes weighing as much as 360 lbs., and Josephus gives many examples of their formidable effects. These instruments are traceable to 1000 years before our era, as we find in 2 Chron. xxvi. 15: Uzziah "made in Jerusalem engines, invented by cunning men, to be on the towers and upon the bulwarks, to shoot arrows and great stones withal." In addition to the machines just named a great many others were used in the 11th, 12th, and 13th Centuries, and even in the 14th after the introduction of fire-arms; among these were the trebuchet, onager, scorpion, and espringal, the motive power of most of them depending upon the same principle, viz. the elasticity of twisted cords formed of the bowels of animals, sinews, human hair, flax, and hemp.<sup>1</sup>

The following short description will serve to explain their respective constructions and uses.

The catapulta (Plate I. Fig. 2) was constructed to throw darts and iron bolts to a distance of some 200 yards, and the balista (Plate I. Fig. 1) stones to a distance of 90 yards.<sup>2</sup> These engines were immensely powerful bows, drawn back by means of capstans, levers, pulleys, &c.; the catapulta having only a single cord for the arrow, and the balista, a broad band formed of several ropes to project the stone, which was placed in a kind of cradle, like a cross-bow.<sup>3</sup> The trebuchet (Plate I. Fig. 4) was used for throwing round stones, barrels filled with Greek fire, or bits of red hot iron; as will be seen by the figure, the projectile force was obtained by liberating the longer arm of the lever, and thus allowing the heavy weight attached to the short arm to fall. The onager consisted of a long arm attached, by an arrangement of ropes forming a spring, to a frame; this arm which had a sling at the end was capable of being confined in a horizontal position, but when released it flew upwards, the sling therefore projecting the stones placed in it. The scorpion was only a large cross-bow. The espringal was a powerful cross-bow mounted on wheels, having ropes and a windlass attached to the frame to bend the bow. Drawings of these machines will be found in the works of Napoleon and Grose, referred to in the notes. The

<sup>1</sup> Grose's Military Antiquities.

<sup>2</sup> *Etudes sur le passé et l'avenir de l'Artillerie*, par Louis Napoleon, Tome II. pp. 46—48.

<sup>3</sup> Wilkinson's Engines of War, and Grose's Military Antiquities.

battering-ram consisted of a long pole or spar headed with iron, usually in the form of a ram's head, and suspended by ropes from a triangle of wood, or else mounted on wheels. This instrument, which was sometimes as much as 120 feet long, was used for breaching the walls of towns and cities, and when impelled by manual force violently against a wall, the vibration produced by the repeated shocks became so great, that the part of the wall thus attacked was eventually thrown down. Josephus says, that no wall however strong was able to resist the attacks of this powerful weapon; and, consequently, no pains were spared by the besieged to nullify its effects by undermining its supports, setting fire to it, &c. The battering-ram was used in Europe so lately as the 14th Century, as a weapon of war; and Sir Christopher Wren employed it in leveling the remains of the old Cathedral of St Paul's, previous to laying the foundation of the present edifice. The towers of war, before spoken of, consisted of several stages or stories, and were of great magnitude; being sometimes as much as 90 cubits in height, and decreasing in size gradually from the bottom to the top. They were mounted on wheels of enormous size and strength, and were used for the purpose of assailing the defenders of the walls of cities and fortified places. The lower stage was usually occupied by a battering-ram, and the others were filled with archers and light armed troops, provided with missiles and combustibles for throwing among the besieged.

Ancient  
accounts of  
guns, and  
pyrotechnical  
compositions.

4. We now come to the consideration of those instruments of war depending on the use of gunpowder, and it will therefore be necessary to make some remarks upon the introduction of that compound, and of other pyrotechnical substances.

The invention of gunpowder has been popularly ascribed to Bartholdus Scharwtz a German monk and alchemist in the year 1320, but it is now well-known, from the writings of Friar Bacon in 1270, that in his time it was a well-known substance usually employed in making fireworks. In a manuscript of Marcus Græcus, generally supposed to have been written between the 9th and 12th Centuries, mention is made of gunpowder and rockets with a suggestion for their uses in war. It is impossible to fix upon the date of the invention, but it appears probable that a compound similar to gunpowder was known both in China and India long before the Christian era, and applied in rockets and shells by those nations to warlike purposes; it was not used for throwing projectiles from fire-arms until a much later period. Amongst the machines constructed by the Chinese, was one called the "thunder of the earth," which is thus described by M. Reinaud, and M. Favé:<sup>1</sup> "A hollow globe of iron was filled with

<sup>1</sup> Du Feu Gregois et des Origines de la Poudre, par M. Reinaud, et M. Favé, p. 176.

a bushel of gunpowder, mixed with fragments of metal, and was so arranged, that it exploded on the approach of an enemy, so as to cause great destruction in his ranks." The "impetuous" dart of the Chinese, was a round bamboo,<sup>1</sup> about  $2\frac{1}{2}$  feet in circumference, lashed with hempen cords to prevent its splitting, and having a strong wooden handle fixed to one end, thus making its entire length about 5 feet. This was then charged with powder of different kinds, arranged in layers, over which were placed fire balls, which being thrown to a distance of 30 or 40 yards by the discharge, consumed any combustible materials they might come in contact with. The Hindoos are also supposed to have had a very early knowledge of gunpowder, and Alexander the Great mentions, in one of his letters, the terrific flashes of flame showered upon his army in India, by its defenders. The dwellers on the banks of the Indus, are said to have made a kind of oil, which being enclosed in earthen jars, and thrown against woodwork, caused so strong a flame as could only be extinguished by having mud thrown upon it. Some suppose this to have been the substance made use of by Gideon, in his attack upon the camp of Midian. A late writer, M. Paravey, has endeavoured to establish the fact, that gunpowder and fire-arms were known to the Chinese long before the Christian era; and it is mentioned in Chinese writings, that in the year 618 B.C. a gun was in use, bearing this inscription, "I hurl death to the traitor, and extermination to the rebel."

The incendiary composition, termed Greek fire, was known to the Emperors of Byzantium as far back as the 7th Century, and the nature of its composition ordered by them to be kept a State secret. In the beginning of the 13th Century the Arabs possessed the secret, and it was soon divulged by them, for the proportions of the ingredients, and the manner of making the Greek fire are mentioned by a Spanish monk Ferrarius, in an epistle to one Anselm, preserved in the Bodleian Library at Oxford. The proportions given in this document are 20 lbs. of saltpetre, 8 lbs. of sulphur vivum, and 5 lbs. of willow charcoal.<sup>2</sup>

The Greek fire appears to have been constantly used by the Saracens against the Christians during the Crusades, and to have caused great consternation from the accounts of the historians of that period. It differed from gunpowder in being of a viscous nature sticking to the object against which it was thrown; it was on land projected in barrels by means of the ordinary machines of the times, or sometimes attached to the heads of arrows; at sea it was thrown by hand enclosed in phials in which it was kept. A crusader who accompanied Richard I. says of it

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<sup>1</sup> Du Feu Gregois et des Origines de la Poudre, par M. Reinaud, et M. Favé, p. 176.

<sup>2</sup> Our Engines of War, by Captain J. W. Jervia, R.A.

"with a pernicious stench and livid flame, it consumes even flint and iron, nor could it be extinguished by water; but by sprinkling sand upon it, the violence of it may be abated, and vinegar poured upon it will put it out."<sup>1</sup>

Guns are said to have been constructed in China, in 757 A.D. for the purpose of throwing stones of the weight of from 10 to 14 lbs. to a distance of 300 paces.<sup>2</sup> Whatever doubts may exist as to the earlier history of artillery among the Chinese, it is almost beyond question, that cannon were extensively used by them in the beginning of the 13th Century, as we have access to various reliable accounts, establishing this fact.

12th and 13th  
Centuries.

5. In 1232 A.D., cannon<sup>3</sup> throwing stone shot are said to have been used against the Moguls, and during this war, certain machines were also employed, which being filled with powder, and ignited at the proper time, burst with a noise like thunder, and whose effect extended for the space of half an acre round the spot where they exploded.<sup>4</sup> We can easily account for the early knowledge of pyrotechnical compositions among the natives of India and China, when we recall to mind the fact, that both saltpetre and sulphur are found in great abundance in those countries; and it seems probable, that this knowledge was communicated by the Hindoos to the Saracens, through whom it reached Europe chiefly by way of Spain. Condé, in his history of the Moors, in Spain, states that, artillery was used by them against Saragossa in 1118 A.D., and that in 1157 A.D., they defended themselves in Niebla, against the Spaniards, by means of machines, which threw darts and stones, through the agency of fire. In 1280 A.D., cannon were used against Cordova, after which period, they are frequently mentioned in the records of Spain. Iron shot appear to have been first used in that country in the beginning of the 14th Century.

14th Century.

6. It is now generally acknowledged that fire-arms were not employed to any extent in Europe until the beginning of the 14th Century. The anecdote related of Schwartz, that having mixed the ingredients of gunpowder in a mortar, and placed a stone on them, they took fire accidentally and projected the stone to some distance, may perhaps have suggested the most effective way of using gunpowder.

The first mention we have of the use of fire-arms, at this period, is in the life of Robert Bruce by John Barbour, arch-deacon of Aberdeen; in which certain engines termed "crakeys of war" are spoken of, as having been used by Edward III. in

<sup>1</sup> Grose's Military Antiquities.

<sup>2</sup> Du Feu Gregois et des Origines de la Poudre, par M. Reinaud, et M. Favé, p. 186.

<sup>3</sup> Histoire des Mongols. M. H. Quatremere, Tome i. pp. 185, 186.

<sup>4</sup> Mailla, Histoire Generale de la Chine, Tome ix. p. 166.

his campaign against the Scots, in 1327; and the same monarch had four guns at the battle of Crécy, in 1346. Froissart mentions these guns in one of his manuscripts, now preserved in the library of Amiens. A free translation of the passage referred to, would run as follows: "And the English caused to fire suddenly certain guns which they had in the battle, to astonish (or confound) the Genoese." Vilani, a Florentine historian, also confirms this statement, as well as a passage in the chronicles of St Denis, which speaks of the use of cannon by the English at Crécy.

In 1338 A.D., amongst the stores of the hulk "Christopher of the Tower of London," were three iron cannon with five chambers, and in the barge "Marie de la Tour" one iron gun with two chambers, and another of brass with one chamber (*Hist. of Royal Navy*, by Sir Harris Nicolas, App. II). The earliest French record is of the same year. "The extensive trade which the Italian States carried on with Mahommedan powers would alone account for their becoming acquainted with gunnery before the north of Europe; but it is remarkable that in Spain, Italy, France, England, and Germany, the dates of the public documents in which cannon are first mentioned, scarcely differ from one another by ten years, a fact which could only have arisen from the manner in which armies were raised in those days. A certain portion consisted of the feudatories of the country whose name it bore, but by far the greater part were mere mercenaries and adventurers, attracted by the prospect of pay and plunder; and who, as they roved from one service to another, carried with them the fame of such as were skilful in smithery, or cunning in devising engines of destruction."<sup>1</sup>

An ancient manuscript also mentions the existence of gunners and artillerymen, whom Edward III. employed when he landed before Calais in 1346, and the several stipends each soldier received. The sentence runs thus: "masons, carpenters, engineers, gunners, and artillerymen, the sum of 12, 10, 6, and 3 pence per diem."

The first fire-arms appear to have consisted of two kinds; a larger one for discharging stones, called a bombard (Fig. 1, Plate 2), and a smaller for propelling darts and leaden balls; both of these were used in 1356, by the Black Prince, to reduce the Castle of Romozantin; and two years later, the artillery of St Valery, did great execution among its besiegers. The guns constructed at this period were of very small calibre, for the art of casting was but little known, and the cost of iron and brass, as well as of the materials for gunpowder was very great. The term "cannon" is derived from the Latin word "canna" a reed;

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<sup>1</sup> *Our Engines of War*, by Captain J. W. Jervis, R.A.

or perhaps, as Fosbroke says, from the large canister which held the charge, and which was disconnected from the gun when the latter was being loaded. The earlier kinds of ordnance were called "bombards," or "bombardæ" from the Greek word "*βόμβος*," expressive of the noise made by their discharge, and they were generally made of wrought-iron bars or plates strengthened with rings of the same material. Robins<sup>1</sup> remarks that the gunpowder first used was a very weak composition owing to the defective construction of the ordnance rather than to the ignorance of a better mixture. Bombs<sup>2</sup> or shells were invented in this century, and were at first made of brass and opened by hinges.

We find in the reign of Richard II. that Thomas Norbury was directed to provide two great and two lesser engines, called cannons, 600 stone shot for the same, with saltpetre, sulphur, charcoal, &c., to be sent to the Castle of Bristol; and in the year following, when Richard attacked the Castle of St Malo, he had as many as 400 cannons in his train. From this period, cannon were used in all the offensive and defensive operations of war; though a considerable time elapsed before it became a really serviceable arm.

15th Century.

7. The calibres of ordnance gradually increased, and at the beginning of the 15th Century brass guns of large size were cast. Thus in 1415, Gerard Spring petitioned Henry V. that a warrant might be issued commanding the Treasurer and Barons of the Exchequer, to grant him a discharge for the metal of a brass cannon called "Messenger," weighing 4,480 lbs., which burst at the siege of Aberystwith; of a cannon called "Kynge's Daughter," burst at the siege of Harlech; and of a cannon which burst in proving. In a contemporary poem of the siege of Harfleur, by Lydgate, the calibre of these pieces is given; "Messenger," threw stone shot 30 lbs. in weight, and "Kynge's Daughter" shot of 45 lbs.<sup>3</sup>

Two wrought-iron guns of the time of Henry VI. (1422—1461) are in the Royal Military Repository, Woolwich, from which the arrangement of bars and rings before described may be clearly seen; five wrought-iron bombards are preserved in the "Musée de l'Artillerie" at Paris, which were, it is said, abandoned by the English at the town of Meaux, in 1422.<sup>4</sup>

Cannon foundries were first established in Germany in 1440, and in France even earlier (1377 according to Piobert). At the end of the 15th Century, artillery carriages with wheels were introduced, and replaced the shapeless beds upon which ordnance

<sup>1</sup> In his *New Principles of Gunnery*.

<sup>2</sup> According to Grose on the authority of Valturius.

<sup>3</sup> *Our Engines of War*, by Captain J. W. Jervis, R.A.

<sup>4</sup> Cheaney, *On Fire Arms*, p. 60.



were at first mounted, trunnions being also given to the guns (Plate II. Fig. 2, 3).

The first projectiles fired from cannon were made of stone; and Guicciardini, the Italian historian, mentions some employed by Mahomet II. at the siege of Constantinople in 1453, which weighed as much as 1200 lbs.<sup>1</sup> As a knowledge of the art of gunnery increased, great improvements took place with regard to projectiles, and balls of iron were substituted in the place of those formed of stone; these were in general used on the Continent towards the end of the 15th Century, and were introduced into England in the 16th Century.

Captain Jervis, in his work previously quoted, remarks upon the great and for the age wonderful knowledge displayed by the celebrated painter, sculptor, and engineer, Leonardo da Vinci. He says, "We thus find him (Leonardo) pursuing his researches from the simplest question in geometry and statics to some of the deepest laws of dynamics, especially those affecting the flight of projectiles, a theory then new amongst mathematicians." Leonardo himself explains his manner of studying phenomena in order to arrive at safe conclusions, thus: "I will treat of the subject, but first of all I will make some experiments, because my intention is to quote experience, and then to shew why bodies are found to act in a certain manner." Leonardo was born in 1452. In the theory of gunnery he appears to have been a century in advance of his contemporaries.

Great improvements were made both in the organization and equipment of artillery by Charles VIII. of France. Upon his invasion of Italy, the rapid movements, perfect equipment, and skilful service of his artillery produced the greatest consternation among the Italians. Queen Isabella of Spain at the end of this century (1483—87) established foundries for the manufacture of ordnance and projectiles, and by a series of unremitting efforts collected one of the finest trains of artillery in Europe, which was of the greatest assistance to her in the wars against the Moors.<sup>2</sup>

16th Century.

8. In all the principal nations of Europe much ingenuity was now exercised in the manufacture of all kinds of artillery matériel. Both Henry VII. and Henry VIII. took great pains to introduce the art of gunnery into the kingdom; and for this purpose brought over a number of Flemish gunners; it is said, that the latter monarch himself, invented small pieces of artillery to defend his wagons. Bronze ordnance were first cast in England in the 1521 in the reign of Henry VIII., and iron cannon afterwards in 1547 in the reign of Edward VI. by Peter Bawd, one of the foreign founders brought over and employed by the

<sup>1</sup> Wilkinson's *Engines of War*.

<sup>2</sup> *History of the reign of Ferdinand and Isabella*, by W. H. Prescott.

late king. The guns cast at this period were of very great length, some 34 or even more calibres long, this being no doubt necessary on account of the large charges of meal powder with which they were fired; the charge for an iron or lead ball was half or two-thirds its weight, but for a stone ball only one-third; ladles and sponges for loading and cleaning the gun were used. The ordnance were very much ornamented and named after birds of prey or serpents, as the *falcon*, the *saker* a kind of falcon, the *culverin* from colubrine a species of serpent, as also the *basilisk* from the serpent of that name. Portable "hand cannons" were introduced which were fired from a rest, and could be served and carried by two men; also ribandequins or organ guns, consisting of a number of tubes placed in a row like those of an organ. Carcasses, grenades, and petards were invented at the end of this century, and howitzers appear to have been adopted by the Germans about the same time.

Tartaglia<sup>1</sup> gives a table of ordnance, which shews how many different natures were then in use; for at that time and even long after the founder's fancy alone seems to have determined the length, weight, and other details of construction of a gun. This table gives seven different culverins, the iron ball for the lightest being 9½ lbs. in weight, and for the heaviest 79½ lbs.; six cannon the iron ball for the lightest 13½ lbs., and for the heaviest 79½ lbs.; these ordnance were for siege and garrison service, oxen being used for their transport. For field service there was the 4-pr. falcon, the 2-pr. falconet, the 6½ and 8-pr. sakers; these pieces were drawn by horses and fired with leaden balls. Besides these there were pieces for throwing stones of from 20 to 165½ lbs. weight. The battle of Remi, in 1554, was the first action in which light field guns, having limbers, were used,—these guns accompanied the cavalry. In a Table of Ordnance, given by Fosbroke, as being a list of the guns used in the time of Elizabeth, and immediately preceding her, we find how little the calibres of iron guns have altered during the last two or three centuries, as these guns have all their antitypes among those of the present day.

	Weight of ball.	Calibre.
	lbs.	inches.
The Cannon Royal .....	66	8.5
Cannon Serpentine .....	53½	7
Bastard Cannon .....	41	7
Demi-bastard Cannon .....	33	6.75
Cannon Pietre .....	24	6
Culverin .....	17½	5.5
Demi-Culverin .....	9½	4
Saker .....	5½	3.5

Tartaglia's work on Gunnery, dedicated to Henry VIII., gives a great deal of information concerning both the theory and prac-

<sup>1</sup> Tartaglia's Three Books of Colloquies concerning the art of shooting.

tice of gunnery as then understood, and proves him to have been a man of great talent and ingenuity. He explains the motion of a projectile taking the resistance of the air into account, the theory of gunpowder, &c., and the accuracy of his conjectures, considering the state of mechanical and other sciences at that time is most surprising. He gives directions for sighting ordnance, and shews the use of the gunner's quadrant which he invented, besides entering into much detail regarding the rules to be observed in the manufacture of ordnance, carriages, and gunpowder. Tangent scales or elevating screws were not then used, as from the diagrams in Tartaglia's work, the trail of the carriage is lowered into a hole in the ground when elevation is required.

17th Century.

9. The beginning of the 17th Century was an important epoch in the History of Artillery, and much attention was given to this branch of the military profession by Henry IV. of France, Maurice of Nassau, and Gustavus Adolphus of Sweden. The former of these distinguished leaders introduced new and improved forms and kinds of missiles, such as tin cases, filled with steel bolts or darts, and canvas cartridges, containing small balls. Gustavus Adolphus introduced really serviceable field guns of a lighter construction than had hitherto been made use of, and he also adopted the use of cartridges, with shot attached, so that these pieces might be discharged eight times before the musket could be fired six. The field guns of Gustavus Adolphus were made of leather and coiled rope over a cylinder of copper.

Galileo, whose *Dialogues on Motion* were printed in 1646, investigated the theory of projectiles, and asserted that their trajectories would be parabolic curves; this however only refers to low velocities, for he declares plainly, that what he calls the supernatural velocities of projectiles fired with high charges from fire-arms will be greatly resisted by the air, and therefore, "that the parabolic lines will be less inclined or curved at the beginning than at the end." For mortar firing he considered that the resistance of the air might be disregarded.

The artillery of Gustavus was admirably organized, and he appears to have first appreciated the importance of causing artillery to act in concentrated masses,<sup>1</sup> a principle now so fully recognized by all artillerists. His leather guns did him good service in the battle of Leipzig (or Breitenfeld), their fire combined with their rapid change of position being the chief cause of his victory. Louis XIV. of France, greatly improved and increased his artillery, and throughout Europe the necessity of lightening field artillery and separating it from position artillery was, about this time, gradually recognized and acted upon. Ricochet fire was introduced at the end of this century by Vauban, who at the siege of Ath in 1697, fully developed its peculiar utility.

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<sup>1</sup> Chesney, *On Fire Arms*, p. 72.

18th Century. 10. During this century great progress was made in perfecting the manufacture of ordnance and carriages, in the organization and equipment of field artillery, and in the theory of gunnery, which latter was fully established as a science by the investigations and experiments of the celebrated Benjamin Robins.

Guns, at this period, were cast hollow by means of a core, which was kept suspended in the centre of the mould while the metal was being run in. Owing, however, to the great difficulty experienced in keeping this core in a perfectly true position, several artillerists deliberated whether guns cast hollow or solid had the preference, and investigations took place as to the possibility of boring the latter; the result of which was, that Maritz, who had a foundry at Geneva, informed the Court of France, in 1739, that he had discovered a method of boring guns and mortars which had been cast solid. He was at once invited to France, and first at Lyons, afterwards at Strasbourg, secretly worked at boring pieces of ordnance, which on trial proved perfectly satisfactory. In the year 1740, a curious experiment in artillery was made at St Petersburg, where guns were cut out of solid ice, from which balls of the same substance were fired repeatedly, without bursting.<sup>1</sup>

In France, Valière, in 1732, greatly improved the matériel of the French artillery, and after him Gribeauval, on the conclusion of the Seven Years' War, may be said to have commenced an entirely new system, which has been followed by all modern artilleries. He separated field from siege artillery, decreased the number of calibres, the charges, and weights of guns, established uniformity in the construction of carriages, introduced iron axletrees, higher limbers, cartridges, elevating screws, and tangent scales. Carronades were introduced (into the British service) in 1779, the chief advantage derived from their adoption being a reduction of windage.

Robins' explanations with regard to rifling the barrels of fire-arms, and substituting elongated for spherical projectiles, will be referred to in the Lectures VIII. and IX. Robins published his *New Principles of Gunnery* in 1742, which work was shortly after translated into French and German, and commented on by Euler, and other distinguished mathematicians. In this work he described his experiments, and ably treated some of the most difficult questions, viz. the explosive force of gunpowder, and the effect of the resistance of the air in retarding and deflecting projectiles. He invented the ballistic pendulum, the value of which invention may be judged from the circumstance that upon the results of experiments with this instrument all modern theories relating to the science of gunnery entirely

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<sup>1</sup> Wilkinson's *Engines of War*, p. 52.

depended until within the last few years. The investigations of Robins were carried on at the end of this century by Dr Hutton, of the Royal Military Academy, Woolwich, who improving the apparatus used by the former, and after a long series of careful experiments, deduced a number of formulæ, from which some of the most difficult problems in gunnery may be approximately determined.

During the wars between France and the allies at the beginning of this century, field artillery was sometimes handled with skill; for instance, Marlborough, at the battle of Malplaquet, advanced forty pieces in line, so as to bear upon a decisive point. It was however during the Seven Years' War that a large force of artillery, and one which possessed great mobility, was employed by the opposing armies, the number of pieces in proportion to the number of troops of other arms being probably greater than it has ever been since. The Austrian artillery was admirably organized by Prince Liechtenstein, and Horse Artillery first established by Frederick the Great.

19th Century. 11. The long wars at the commencement of this century gave ample opportunities for the employment and improvement of artillery of all kinds. The invention of the shrapnel shell, by Major Shrapnel in 1803, and the transformation of the rocket from a mere signal to a destructive projectile, by Sir W. Congreve in 1806, gave increased power to the fire of artillery. The whole system of fire-arms is now however undergoing a complete revolution, in consequence of the introduction of rifled arms and elongated projectiles; rifled small arms have now become general in all the European states, at least in those of any importance, and in America, and all are endeavouring to procure the most efficient rifled ordnance. Rifled small arms with spherical balls had been used for some years previous to the adoption of elongated projectiles (by the French in 1846), but the very great accuracy and long ranges of the present rifles depend almost entirely upon the employment of elongated projectiles. The Emperor Napoleon III., by the introduction of the 12-pr. gun, greatly simplified the ordnance, carriages, and ammunition of his field artillery, and he has been the first to employ rifled cannon in the field,<sup>1</sup> during the late Italian campaign of 1859; he has also written a most excellent history of artillery, entitled, "*Etudes sur le passé et l'avenir de l'Artillerie.*" Sir W. Armstrong, by his great mechanical skill and knowledge of the principles of gunnery, has produced the most perfect rifled cannon hitherto made, the accuracy of its fire being most remarkable, as well as the excellence of its construction.

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<sup>1</sup> This applies merely to rifled field pieces, for the English employed guns at the siege of Sebastopol in 1854, rifled on Mr Lancaster's principle.

Many able men have written works upon the theory, application, and tactics of artillery. Gregory, Poisson, Piobert, Didion, Magnus, Mallet, and Mordecai, have investigated numerous theories connected with the several branches of the science.<sup>1</sup> Paixhans and Douglas have treated more especially the application of gunnery; while the tactics and manœuvres have been examined by Decker, Grewenitz, Taubert, and Okounef. The introduction of the rifle principle to fire-arms, and the general adoption of elongated projectiles have rendered the theories hitherto held so complicated that numerous experiments or trials will have to be made before satisfactory data is obtained, upon which any reliable mathematical reasoning can be grounded. Much greater accuracy in experiment can however now be obtained by the electro-ballistic apparatus,<sup>2</sup> than with the ballistic pendulum.

Napoleon relied greatly upon this arm, and gave numerous examples of the effect produced by the skilful use of large masses of artillery in the field of battle. The allies were not slow to adopt a similar tactical principle, which has been of late years carried out, especially by Russia, as evidenced in the taking of Warsaw, in 1831. In fact the great importance of artillery as a principal arm is now generally acknowledged and universally acted upon, as for example in the Crimean and Italian campaigns, and especially by the British in the late Indian and Chinese wars.

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<sup>1</sup> Captain Boxer, R.A., has written the first part of a *Treatise on Artillery*, which when complete, will doubtless be of great value.

<sup>2</sup> This invention will be again referred to in *Lecture VII. on Gunnery*.

## CONSTRUCTION OF GUNS.

1. BEFORE commencing this subject it is desirable to explain the meaning of several terms, which may occur in the following remarks :—

Five principal parts of a gun.

2. A gun of ordinary construction (Fig. 1, Plate 3) is divided into five principal parts, viz.

The Cascable, from *F* to *A*,  
First reinforce *A*—*B*,  
Second do.... *B*—*C*,  
Chase..... *C*—*D*,  
Muzzle ..... *D*—*E*.

Rings, &c.

3. The exterior of a gun is more or less ornamented with rings, astragals, &c., according to the fancy of its constructor; these, however, are now looked upon as objectionable, increasing the expense of manufacture, and very probably decreasing the strength of the piece.<sup>1</sup>

Breech.

4. *cd* is called the breech.

Dispart.

5. *ab* which is half the difference between the diameters of the base ring and swell of the muzzle is termed the dispart.

Length of gun.

6. The length of a gun is measured along its axis from *A* behind the base ring, to *E* at the face of the muzzle.

### *General Principles.*

7. The most important points to be considered in the construction of a piece of ordnance, are (1) the bore, its form and length; (2) the exterior form of the gun, depending upon the weight and distribution of the metal; and (3) the preponderance and position of the trunnions. Other minor points will also be noticed.

### *Bore.*

8. The general form of a projectile being that of a sphere or cylinder (pointed), it is obvious that the bore of a gun should be cylindrical in shape, except when modified to a certain extent by the introduction of a chamber, or some peculiar mode of rifling.

Calibre.

9. The diameter of the bore is termed the "calibre" of the gun.

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<sup>1</sup> This latter refers to cast ordnance.

Windage, why  
necessary.

10. It is necessary that the diameter of the bore of an ordinary gun (smooth-bored) should be slightly larger than that of its projectile, for the following reasons :—

(1) In consequence of the impossibility of casting shot (or shell) either perfectly spherical, or of uniform diameter.

(2) To allow for increase in the diameter of the projectile, from the incrustation of rust, or from its expansion when heated.<sup>1</sup>

(3) From the foulness of the bore during continued firing.

11. Until lately there was also another reason, viz. from the mode of attaching wooden bottoms to projectiles by means of tin strapping; this has, however, been discontinued in our service, except in peculiar cases; Captain Boxer's "rivet" having been substituted for the strapping.

Definition of  
windage.

12. The difference between the diameter of the bore of the gun, and that of its projectile, is termed the "windage."

Disadvantages  
of windage.

13. The disadvantages arising from windage are,—

(1) The loss of a certain portion of the force of the charge, due to the escape of the elastic fluid round the projectile.

(2) Irregularity in the flight of the projectile.

(3) Injury to the bore of the gun.

With regard to the first point, as there is a loss of a certain portion of the gas, there will also be a proportional loss of initial velocity; it has been found that with small differences of windage, the loss of velocity by windage is proportional to the windage. (Boxer, p. 56).

Irregularity in the flight of the projectile, in consequence of the windage, arises from the fact that, the centre of the ball is below the axis of the piece, and therefore, the elastic gas acts in the first instance upon the upper portion of the projectile, driving it against the bottom of the bore; the shot re-acts at the same time that it is impelled forwards by the charge, and strikes the upper surface of the bore some distance down, and so on, by a succession of rebounds, until it leaves the bore in an accidental direction, and with an uncertain rotation, depending chiefly upon the last impact. (Fig. 1, Plate 4).

The bores of all guns, but especially of bronze guns, are more or less injured by the rebounds of the shot in passing through them;<sup>2</sup> these rebounds increase materially with the

<sup>1</sup> The expansion of the diameter of shot when heated, is from about  $\frac{1}{16}$  to  $\frac{1}{12}$ .

<sup>2</sup> An experiment was lately made at Shoeburyness in order to determine how far the bore of a bronze gun is protected from injury by the use of the sabot. Two 9-pr. guns were fired, one with loose shot, and the other with shot having sabots riveted to them in the usual way. The former was declared unserviceable at the 90th round, its bore being very much indented, and the exterior even bulged



windage. The first impact, viz. at the seat of the shot is of the greatest importance, as from its position, it is the most likely to render the piece unserviceable. This injurious effect is in a measure prevented by the use of wooden bottoms or sabôts, which are attached to shot for bronze pieces, as well as to all shells.

Amount of  
windage for-  
merly allowed.

14. The calibre of the gun and the amount of windage were originally determined from the diameter of the shot; this diameter being divided into 20 parts, one was allowed for the windage, thus making the calibre  $\frac{19}{20}$  of the diameter of the ball. Dr Hutton states, that even with this small degree of windage, "no less than between one-third and one-fourth of the powder escapes and is lost; and as balls are often smaller than the regulated size; it frequently happens that half the powder is lost by unnecessary windage."

15. In the carronades, which were introduced into the service in 1779, the ordinary windage (of  $\frac{1}{16}$  diameter of ball) was greatly reduced; this was effected by lessening the calibre of the carronades, as no alteration was at that time made in the windage of guns.

16. In consequence of a proposal by Sir H. Douglas to reduce the windage of ordnance, of field guns to  $\cdot 1$  inch and of heavy ordnance to  $\cdot 13$  inch, experiments were carried on, in 1817, by a Committee of Artillery Officers (assisted by Dr Gregory of the R.M. Academy) in order to determine the effects of such reductions on the ranges, bores of guns, &c. From a number of trials with 6, 9, and 12-pr. guns (bronze) it was established "that with charges of powder one-sixth less than usual, the larger shot and smaller windage produced rather the longest ranges;" and also, that the bores of bronze guns are less injured with the diminished windage.

This Committee recommended that the windage of field guns should be reduced to  $\cdot 1$  inch, and of siege and garrison guns to  $\cdot 15$  inch.

Amount of  
windage in  
the Service  
Ordnance.

17. The windages of all ordnance are given in the Plates of Guns, and also in the Table of Dimensions in Lecture III: the following remarks will, however, give a general idea of the amount of windage in the different kinds of ordnance in the service:—

The windage of field guns is  $\cdot 1$  inch; of iron guns and howitzers, from  $\cdot 125$  to  $\cdot 233$  inch, with the exception of a few guns, as the 18-prs. bored up from the 9 and 12-prs., which

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over one part of the indentation; moreover, at the last round the shot broke, owing no doubt to its jamming, in consequence of the bore being so much deformed in shape. The latter gun, with which sabôts were used, was uninjured at the 100th round.

have but .071 inch. Iron 13, and 10-in. mortars, both land and sea service, have .16 inch; and the small brass mortars have .025 for the royal, and .066 for the coehorn.

Chamber.

18. The chamber of a piece of ordnance is a cell or cavity at the bottom of the bore to receive the charge of gunpowder. Mortars, howitzers, and shell guns, which have comparatively small charges, are provided with chambers, as a greater useful effect is thereby obtained from the powder (Boxer, p. 82).

19. There are two forms of chambers in use in our service, viz. the cylindrical and conical or gomer chamber. (Figs. 2, 3, Plate 4).

The cylindrical chamber is best adapted to very small charges; the gomer is suitable for larger charges.

20. The gomer chamber was originally proposed for mortars, and it possesses the following advantages,—that when the shot is “home,” all windage, until the shot has moved, is destroyed; also, that the axis of the projectile in this case is in the same line as the axis of the bore of the piece, the force of the charge therefore acting uniformly upon the projectile, or through its axis. Should the bore of a gun, having a gomer chamber, be horizontal or nearly so, the shot will rest upon the bottom of the bore, and the above advantages will not be obtained. In order to remedy this defect, Sir H. Douglas states, that it is the practice on board the “Excellent,” to set the shot well home with a wad, thus forcing it up the lower part of the conical surface, and, as far as possible, into the chamber.

21. The cylindrical chamber may be regarded as obsolete in our service, the only pieces having this form of chamber being the 24-pr. iron howitzer, the coehorn howitzer, and carronades. All shell guns, mortars, 8-inch and 10-inch howitzers, and brass howitzers have gomer chambers.

22. The French Paixhans guns have chambers in the form of a cylinder, terminated towards the muzzle by a frustrum of a cone (Fig. 4, Plate 4). The Americans have also adopted this form.

For other particulars with regard to the advantages, &c. of various forms, see Boxer, p. 82—85.

Length of bore.

23. The length of the bore of a piece of ordnance must be such as to allow of the decomposition of its whole charge, a certain time being necessary for its complete combustion. If the bore be not of sufficient length for this purpose, a considerable portion of the charge will be blown out unfired, and therefore wasted.

24. The initial velocity of the shot increases with the length of bore up to a certain point, viz. when the retarding forces of the friction of the ball against the sides of the bore, and the resistance of the column of air in front of the ball (which increases with the velocity) are equal to the accelerating force of the gas (Boxer p. 63). Experiments have been made at different times by Colonel Armstrong, Dr Hutton, &c. to ascertain the most advantageous length for the bores of guns; these are described in Boxer's Treatise, pp. 63—71, and a curious law is also noticed from the Tables of Practice given, "That guns of certain lengths, in calibres, give relative maxima ranges;" this law would only apply to smooth-bored ordnance. In the experiments of 1801, relative maxima ranges were obtained from guns of 12, 15, and 19 calibres in length.

It would, at present, be impossible to give principles upon which the lengths of rifled ordnance should be based, so many different points requiring numerous and careful experiments in order to furnish sufficient data for the proper consideration of the subject.

Comparative Lengths of Service Ordnance in Calibres.

Guns.	Length.	Howitzers and Mortars.	Length.
	cal.		cal.
10-in. of 86 cwt. ....	11·3	Iron howitzers .....	6
8-in. 65 " .....	13·5	Bronze " .....	10.
do. 52 " .....	12	13-in. mortar, S. S. ....	4
68-pr. 95 " .....	14·7	10 " " S. S. ....	4·5
32-pr. 68 " } .....	17·8	13 " " L. S. ....	3
do. 56 " } .....		10 " " L. S. ....	3·1
do. 50 " .....	16·9	8 " " L. S. ....	3·1
24-pr. 50 " .....	19·5	5½ " " .....	2·3
18-pr. 42 " .....	20·4	4½ " " .....	2·6
Bronze field guns .....	17		

25. The length of the bore will, however, be limited by several practical considerations, such as the weight of the piece, the space it will have to occupy, &c.

Exterior Form.

General principles.

26. The external form of guns in general use is that of three truncated cones joined together, their bases being towards the breech:<sup>1</sup> and to these are added the cascable in rear, and the muzzle in front. The reason for this construction is that, the force of the gas produced by the explosion of gunpowder is inversely as the space in which it is confined; and consequently, this force decreasing gradually from breech to muzzle, the thickness of metal may be reduced accordingly, thereby making the gun lighter without affecting its strength.

<sup>1</sup> The Armstrong, and some other guns of wrought-iron, are not conical in form, but composed of several cylinders of different thicknesses, some of them however slightly tapering, and the thickness of metal decreasing from breech to muzzle.

27. It is necessary in the first place, to endeavour to determine what thickness of metal is required for that part of the gun at the breech, and surrounding the charge, for it is here where the greatest strain from the explosion of the charge will be exerted. No precise rules can be laid down for the regulation of this thickness in various kinds of ordnance, as so much depends upon the physical properties of the material used, these properties being but imperfectly understood; the general results of experience, or of experiments carried on for the purpose of establishing this point can alone furnish us with the requisite data.

28. The calibre is taken as the unit of measurement in the construction of ordnance.

29. The thickness of metal in a gun, will chiefly depend upon the charge with which it is intended to be fired, and also upon the weight and form of the projectile.

Amount and thickness of metal in service (smooth-bored) guns.

30. For bronze guns, the following rules have been adhered to:—medium brass guns, as 12 and 9-prs., with charges of 4 lbs., and 2 lbs. 8 oz.<sup>1</sup> respectively, have  $1\frac{1}{2}$  cwt. of metal to every 1 lb. of shot; the thickness of metal at the breech is  $\frac{1}{4}$ , and at the muzzle  $\frac{1}{8}$  calibre. The light 6-pr., with a charge of  $\frac{1}{4}$  the shot's weight, has 1 cwt. of metal to every 1 lb. of shot; the thickness of metal at the breech being  $\frac{1}{4}$ , and at the muzzle  $\frac{1}{8}$  calibre. The charge for bronze howitzers is from one-seventh to one-sixth, and there are in these pieces about 96 lbs. of metal to 1 lb. of shell.

31. The ordinary cast-iron guns of the old construction (Blomefield's) with charges of  $\frac{1}{3}$  the weight of the shot, have from  $1\frac{1}{2}$  to 4 cwt. of metal to every 1 lb. of shot; the thickness of metal at breech in these guns, in terms of the bore are as follows:—

Pr.	Calibre.
42 .....	1
32 .....	$1\frac{1}{8}$
24 .....	$2\frac{2}{8}$
18 .....	$1\frac{3}{8}$
12 .....	$1\frac{4}{8}$
9 .....	$1\frac{5}{8}$
6 .....	$1\frac{6}{8}$
3 .....	$1\frac{7}{8}$

Thus increasing  $\frac{1}{8}$  as the calibre decreases; the thickness at the neck of the muzzle is half that at the breech in these guns.

<sup>1</sup> This charge was formerly 3 lbs., all medium guns having a charge of one-third weight of the shot; the charge was decreased when its windage was reduced.

32. In cast-iron guns of more recent construction, the metal is distributed upon different principles, viz. in giving a greater thickness of metal, and consequently more strength to the first and second reinforce, especially the former, which surrounds the charge, while the amount of metal in the chase is diminished, this part having to sustain but a small proportion of the strain from the discharge of the piece; also, in increasing the proportional thickness of metal, as the calibre of the gun is greater; several rings, astragals, &c. have, moreover, been omitted in the latter constructions of guns.

Congreve's  
gun.

33. Sir W. Congreve, proposed a 24-pr. gun of conical form (see Plate XI.) in 1813, which had a much greater thickness of metal at the breech than those of the old construction; the extra thickness was by him supposed to give a re-acting power to the gun, which, however, is an erroneous idea, not supported by facts. He assumed, "That the propelling or re-acting power of a piece of ordnance may be increased by augmenting the quantity of metal about the charge, though a greater quantity be taken from other parts; and, consequently, that a lighter gun may have a greater propelling power than a heavier one, by a judicious distribution of metal."

Millar's shell  
guns.

34. In the shell guns, introduced into the naval service, by Gen. Millar, in 1824, the thickness of metal at the breech is considerable, and comparatively slight in the chase; the metal of the 1st reinforce in the 8-inch of 65 cwt. is cylindrical in form, that of the 2nd reinforce being slightly conical, and of the chase, still more so (see Plate III.). The 10-inch has a charge of about one-seventh the weight of its shell, and the 8-inch, about one-sixth; in the 10-inch, there is about 1 cwt. of metal to 1 lb. of shell, in the 8-inch (65 cwt.), about 145 lbs. to 1 lb. of shell. (Fig. 2, Plate 3.)

• Monk's guns.

35. Mr Monk of the Royal Arsenal, proposed to increase the thickness of metal of guns at the breech, and diminish it in the chase, without however adding to the amount of metal in the piece. Some 56-pr. guns were cast in 1838, upon his principle, and 32-prs. afterwards; the former, however, are no longer supplied to the service, as they are generally considered deficient in strength.

Dundas' guns.

36. Col. Dundas introduced guns of somewhat similar form to those of Monk, but not so conical, having a greater thickness of metal in the 1st and 2nd reinforces. His 68-pr. (95 cwt.) is usually considered to be the most efficient smooth-bored gun in the service, and his 32-pr. of 58 cwt. was intended to supersede

the 32-pr. of 56 cwt. of Blomefield's construction. (Fig. 1, Plate 3).

**Iron howitzers.** 37. Iron howitzers, 8 and 10-inch, are constructed to bear a charge of one-twelfth the weight of their respective projectiles, and have about 52 lbs. of metal to 1 lb. of shot.

**Carronades.** 38. Carronades were also constructed for a charge of one-twelfth the weight of shot, and have about 60 lbs. of metal to 1 lb. of shot. (Fig. 4, Plate 3).

39. Tables of Dimensions, Weights, Charges, &c. of Ordnance, are given in Lecture III. In Boxer's Plates of Guns, already referred to, all these particulars for every smooth-bored gun in the service will be found.

**Armstrong guns.** 40. In the Armstrong guns which are of wrought-iron, the amount of metal in each nature is as follows :—

The 6-pr. has 59·83 lbs. of metal to 1 lb. of projectile.			
	12-pr. „	80·58 .....	do
(L. S.)	25-pr. „	73·4 .....	do
(S. S.)	25-pr. „	55·84 .....	do
	40-pr. „	86·25 .....	do
	100-pr. „	89·6 .....	do

From this it appears that, with the exceptions of the 12 and 25-prs. (S. S.) guns, there is a greater proportional weight of metal in a piece as the calibre increases; the 12-prs. being made before the others have probably more metal than is absolutely required as far as regards strength, yet if lighter the destructive effect upon their carriages would be increased (Art. 47); the 25-pr. (S. S.) is similar to the 25-pr. (L. S.), except that it is shorter, which accounts for its weighing less. The charge for these guns is generally  $\frac{1}{12}$  weight of the projectile, and as there is no windage, the whole charge is most probably ignited before the projectile leaves the bore, none of the powder being therefore blown out unfired.

**Increased strain upon ordnance of large calibre.** 41. The larger the calibre of the gun, the greater will be the strain exerted upon it from the explosive effects of the charge, the density of shot being alike, and the weight of charge bearing always the same proportion to that of shot. For, the weight of the ball increases as the cube of its diameter, the strain from its re-action being in the same ratio; also, as the calibre is greater, the mass of the charge increases more rapidly than the surface of the bore upon which it acts, the former increasing as the cube of the calibre, and the latter, as the square of the calibre; in addition, the proportional loss of force from the escape of gas by windage is less as the calibre is greater, the windage (linear) being the same. (Fig. 5, Plate 4).

Increasing the proportional thickness of metal as the calibre decreases, according to the old construction, would therefore appear a wrong principle to be adopted in the construction of ordnance, and is not followed out, but reversed in some of the later cast guns, thus,—

	Calibre.
Monk's 32-pr. has a thickness of	1·114 at breech.
Dundas' do .....	1·14 .....
———— 68-pr.....	1·182 .....

American experiments to determine the gradual decrease in thickness of metal of a gun.

42. Experiments have been carried on in America, to determine the gradual decrease of strain upon the metal of a piece of ordnance, from breech to muzzle; the experiments are thus described :—“By perforating a gun in several places, from the exterior to the bore, at right angles with the bore, and successively screwing a pistol barrel, containing a steel ball, into each perforation, and discharging the gun with the pistol barrel at the different perforations, the relative velocities with which the pistol ball is forced out at these different positions, indicate the force exerted there to burst the gun; and, consequently, the relative strength of metal necessary in the various parts to resist explosion. The results of these experiments are relatively as follows, in decimal parts :—

	Calibre.
“ At one calibre in rear of centre of shot	·9758
— centre of shot .....	1·
— 1 calibre in front of shot.....	·8149
— 2 .....	·6767
— 3 .....	·6163
— 5 .....	·5291
— 7 .....	·4393
— 9 .....	·3988
—11 .....	·3667
—15 .....	·2858

“These decimals shew the relative strength necessary at different parts to resist explosion.”<sup>1</sup>

Dahlgren's gun.

43. A heavy cast-iron gun (11-inch), the exterior form of which was determined by experiments similar to the above, was introduced into the American Navy, by Commander Dahlgren. From *A* to *B* (Fig. 5, Plate 3) the metal is cylindrical, and from *B* to the muzzle, there is a gradual diminution, the chase being very slight.

Strain upon the metal of a gun increases with angle of elevation.

44. It is generally said that the strain upon the metal of a piece of ordnance increases with the angle of elevation at which it is fired. For it is asserted, if a gun be fired “point-blank,” or with its axis horizontal, the force of gravity will merely cause friction between the ball and the bottom of the bore (Fig. 6, Plate 4).

<sup>1</sup> Ordnance, Gunnery, and Steam, by Lieut. Ward, U.S.N.

But should the piece have considerable elevation as in the case of a mortar (Fig. 7, Plate 4), if the force of gravity be resolved into the two components  $a$  and  $b$ ,  $b$  will act directly against the force of the gas from the gunpowder, the component,  $a$ , causing friction. It may be however observed, that  $b$  is so very small in comparison with the immense force exerted upon the projectile by the gas, that it could not possibly cause sufficient increase of resistance to augment the strain on the gun to any appreciable extent. The reason of the strain increasing with the angle of elevation is, no doubt, that as the angle is greater so the gun is less able to recoil, a part of the work therefore, which at a low angle would be expended in producing motion is exerted upon the gun.

Strain upon  
the metal of a  
rifled gun.

45. The strain upon the metal of a rifled piece will be much greater than upon that of a smooth-bored gun of equal calibre, if both are fired with similar charges and projectiles; for with the former piece there will be either less windage or none at all, according to the mode of rifling, the escape of gas being therefore diminished or prevented; the projectile, also, instead of merely rolling through the bore will experience considerable friction at those parts which enter the grooves, and must have a motion of rotation as well as of progression, a greater force being consequently required to move it, the gas being more condensed, and exerting a greater pressure in the gun. Rifled guns being fired with elongated projectiles of much greater weight than the spherical used with smooth-bored pieces, this strain upon the metal would be therefore still more increased, if the charge was not diminished; this is however done, for besides decreasing the strain upon the metal of the piece, it is found that the smaller charge will give quite as high a velocity as is required, the heavy elongated projectile maintaining its velocity longer than the lighter spherical ball; moreover, only a small portion or none of the gas escaping by windage, a greater proportional useful effect is obtained from the powder.

Mortars.

46. On account of the vertical direction in which the force of recoil acts, tending to destroy both the piece and bed (see Art. 47), mortars require a much stronger construction than guns or howitzers (in proportion to their charges); this is also necessary in consequence of the great comparative weight of their projectiles. (Fig. 3, Plate 3).

The following Table gives the largest charges, weight of mortar, and weight of projectile (shell filled) in the Service iron mortars, but it must be remembered that they are seldom fired with such high charges as those in the Table.



	Charge.	Weight of Mortar.	Weight of Projectile.
	lbs.	cwt.	lbs.
13-inch Mortars, S. S. ....	20	100	204
do L. S. ....	9	36	...
10-inch Mortar, S. S. ....	9.5	52	92
do L. S. ....	4	18	...
8-inch Mortar .....	2	9	48

A certain amount of weight necessary in a gun.

47. It will hereafter be seen, in considering the strain upon a gun carriage, that it is necessary to have a certain amount of weight in a gun; for if it were made very light (could a sufficiently strong material be found), the velocity of recoil of the piece would be so great that the carriage would not only recoil to a very inconvenient distance, but would soon be destroyed by the destructive shocks exerted on it by the gun.

Swell of the muzzle.

48. The thickness of metal is increased in guns and howitzers at the muzzle, forming what is called the tulip or swell of the muzzle; additional strength is required at the muzzle, as it is liable to be struck by the enemy's shot, and if not sufficiently strong, would be rendered unserviceable by a very slight blow. The swell also affords a good position for a sight. It is moreover stated, by some writers on artillery, that the thickness of metal must be increased at the muzzle, in order to resist the tendency of the gas to escape in all directions at the mouth of the gun, the ball impeding the gas and causing it to re-act upon the lips of the piece, (see Ward, &c.) Wrought-iron guns of recent construction are generally made without a tulip.

Unequal strain upon exterior and interior of a cast gun.

49. If a gun be cast in one mass, as in the case of an ordinary cast-iron gun, the external portions of the metal do not bear an equal share of the strain (from the discharge) with the interior portions. If *ABC* (Fig. 8, Plate 4) represent the transverse section of a gun, 1 foot (or any other unit) in length, let us suppose the thickness of metal *AD* to be divided into a number of concentric rings.

It is evident that the greater the distance of any ring from the axis of the gun *E*, the less will it be stretched by the expansion of the bore when the piece is discharged; and, consequently, the less will it contribute to the general strength of the gun.

If the strain upon the bore from the discharge be considered merely as a pressure (statical force), the resistance offered to it by any two rings will be inversely proportional to the squares of their circumferences or distances from the axis of the gun. (Barlow, *On Strength of Materials*, p. 203).

It will therefore appear that there is a certain limit, beyond which it would be useless to increase the thickness of metal, viz. when the force exerted upon the surface of the bore would be sufficient to rupture the interior portions of the metal before the strain acted to any extent upon the exterior.

Methods adopted for equalising the strains upon exterior and interior portions of metal of a gun.

50. In order to obtain the requisite strength with a moderate thickness of metal, it would be desirable to equalize, as far as possible, the strains upon every portion of the metal; this would be accomplished by giving the exterior portions a certain initial "tension," gradually decreasing and passing into "compression," towards the interior. Considerable practical difficulties arise in carrying out this principle, but many experiments have been made during the last few years for this purpose. This equalization of the strain upon the metal of a gun has been attempted in various ways, viz. by "shrinking"<sup>1</sup> or "driving"<sup>2</sup> on rings of wrought-iron over a cast-iron cylinder or bore; or by merely turning down an ordinary cast-iron gun to the form of a cylinder from breech to trunnions, and shrinking wrought-iron rings over this portion; or by winding iron wire over an inner tube of cast-iron or other material; also, by constructing the gun of two different materials, as wrought-iron over a steel bore. In shrinking on iron rings, they contract when cool, and thus compress the inner portions of the metal over which they are placed, at the same time, these outer rings will evidently be in a state of tension.

51. Ordnance constructed at an early date (as "Mons Meg" of Scotland, in the 15th Century), were sometimes made by shrinking iron hoops over longitudinal bars or staves of iron; this construction is defective, for, the longitudinal staves take but little of the strain, and are liable to be separated by the penetration of the gas between them.

Mallet's mortar.

52. A monster mortar of 36-inch calibre, was constructed in 1857, by Mr Mallet, by shrinking a number of wrought-iron rings one over the other, and strengthened on the outside by longitudinal bars. At the first experiment, the mortar was ruptured after a few rounds, with a comparatively small charge, in consequence of the imperfect welding of the rings; at the second trial, the rings stood well, but the bolts which secured the longitudinal bars, not being sufficiently strong gave way.

*Preponderance and Position of the Trunnions, &c.*

53. The trunnions of a gun or howitzer are placed a little in front of the centre of gravity of the piece, to allow the breech to preponderate; this is necessary, in order that the gun may rest steadily on its carriage. The excess of weight in rear of the trunnions is termed the "preponderance," and it is desirable that this preponderance should be as small as possible, in order to avoid unnecessary labour in raising the breech of a gun when elevating.

<sup>1</sup> In guns thus strengthened the cast-iron interior has generally given way.

<sup>2</sup> In Captain Blakely's gun this was done, and it stood the most severe trials at Shoeburyness in 1856 and 1857.

54. In order to determine the position of the axis of the trunnions which shall allow of any required preponderance, it will be necessary, in the first place, to find the centre of gravity of the gun; this may be done as follows:—

To find the centre of gravity of a gun.

Divide the gun into a number of portions, each having a distinct form. Find the content<sup>1</sup> of each portion, its moment (content into distance of its centre of gravity) about a point in the axis at the face of the muzzle; add together the moments of all the portions subtracting the moment of the bore and divide this sum by the sum of the weights of the portions, minus the weight of the cylinder of metal bored out from the gun, and the quotient will be the distance of the centre of gravity of the piece, from the face of the muzzle.

Area.

55. The area of a section, or the solid content and moment of each portion may be readily determined by Simpson's rule. In Fig. 9, Plate 4, divide the area  $ABCD$  by an odd number (3 may here be taken) of equidistant ordinates  $a$ ,  $b$ , and  $c$ , and let  $i$  represent the distance between  $a$  and  $b$ , or  $b$  and  $c$ ; then

$$\text{area of } ABCD = \frac{1}{3} i (a + 4b + c).$$

Solid content.

If the solid content of a portion  $ABCD$  be required,  $a$ ,  $b$ , and  $c$  must be taken to represent the areas of equidistant sections, then

$$\text{Solid content of } ABCD = \frac{1}{3} i (a + 4b + c).$$

Moment.

To find the moment of  $ABCD$  about any point  $f$ , taking  $a$ ,  $b$ , and  $c$  for areas, as before.

$$\text{Moment of } ABCD = \frac{1}{3} i (a \times af + 4b \times bf + c \times cf).$$

Having found the solid content of the whole, or any portion, and knowing the weight of a cubic inch of the metal of which the gun is composed, the weight of the whole, or of the portion, can be easily determined.

To find the position for the axis of trunnions, according to the required preponderance.

56. The distance of the centre of gravity from the face of the muzzle being determined, by the above method, the position of the axis of the trunnions may be found thus:—supposing the required preponderance to be one-tenth, divide the distance from the centre of gravity to face of the muzzle (Fig. 10, Plate 4) into  $10 + 1 = 11$  parts; then, by the principle of the lever, the position of the axis of the trunnions will be at the distance of one part from the centre of gravity.

Preponderance of guns in the service.

57. The preponderance varies in different guns in the service between one-eleventh and one-fifteenth of the total weight of the piece, except in Monk's guns, which have one-ninth. Any preponderance above what is absolutely necessary to keep the gun steady is very objectionable, especially in heavy guns, entailing as it must do a great deal of unnecessary labour in raising the breech.

<sup>1</sup> The solid contents may be taken instead of the weights to which they are proportional.

58. In the American Ordnance Manual, in a work on *Gunnery and Steam*, by Lieut. Ward, U.S.N., and in *l'Aide Mémoire de Gassendi*, the definition of preponderance is similar to that given above, but in the late French works *Traité d'Artillerie*, par Piobert, and *l'Aide Mémoire*, for the French artillery (Edit. 1856), the following definition is given, which will apply to their ordnance:—"In cannon and howitzers the preponderance is the pressure supported by the elevating screw, when the piece rests on its trunnions, its axis being horizontal, friction not taken into account." This preponderance in French ordnance laid down in tables, and calculated on the hypothesis that the metal is of uniform density throughout the whole length of the piece, is about

$\frac{1}{10}$  weight of piece for siege and garrison guns.

$\frac{1}{11}$  do field guns.

The actual preponderance however exceeds this, being about

$\frac{1}{17}$  weight of piece for siege and garrison guns.

$\frac{1}{18}$  do. field guns.

#### Trunnions.

59. The trunnions should be of equal diameter, and have one common axis perpendicular to that of the gun; they are usually about one calibre in diameter and length.

In the smooth-bored guns of the service, the axis of the trunnions is placed below that of the piece, which causes the impulse exerted upon the elevating screw, and the destructive effect upon the carriage from the discharge of the piece to be much greater than if it was placed in the same plane with the axis of the piece; this will be fully explained, when considering the effect of the discharge of a gun upon its carriage.

Various reasons have been given for thus placing the axis of the trunnions below that of the piece, among others the following:—that the trunnions are strengthened by being placed in this manner;—that the gun can be laid more readily by means of the quarter-sight;—and that the recoil of the gun carriage is lessened: these reasons would scarcely be considered of much importance at the present day. In America, France, and several other countries, the axis of the trunnions is placed in that of the piece, and it was proposed<sup>1</sup> to do the same in guns for the service; the axis of the trunnions of an Armstrong gun passes through the axis of the piece.

#### Vent.

60. The vent of a piece of ordnance is a small channel, by means of which it is fired, passing through the metal from the exterior surface on the top of the breech into the bore; the vent

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<sup>1</sup> By Colonel Eardly-Wilmot, R.A.

is in a plane at right angles to the axis of the piece, but slightly inclined to it. (For different positions of vent, see Boxer's *Treatise*, Arts. 158—163, p. 61). The vents of all smooth-bored ordnance are made  $\frac{3}{8}$ -inch in diameter, and the tubes with which they are fired  $\frac{1}{8}$ -inch; the latter therefore fitting readily into the former. The vent is not drilled in the metal of the gun but in a copper bouch, which is screwed into the piece, copper being used in consequence of the peculiar property it possesses of withstanding the action of ignited gunpowder better than other metals.

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## GENERAL DESCRIPTION

OF

## ORDNANCE.

1. ALL ordnance employed in the service, may be divided into three classes, viz.

Guns, mortars, and howitzers.

2. Carronades are nearly obsolete, although a certain number are still supplied to the navy, and a few will be found mounted in some garrisons, and coast batteries. Ordnance may also be divided into smooth-bored and rifled or into muzzle-loading and breech-loading; in order however to simplify these distinctions it may be stated here that, in our service, the breech-loading arrangement is only applied to rifled ordnance, and that there are a certain number of rifled guns, but at present no rifled mortars or howitzers.

### *Smooth-bored Guns.*

Classification  
of guns.

3. Guns are used for projecting shot and shell, horizontally, or at very low angles, and as they are fired with large charges of powder, which are fixed for each nature of gun, very great strength and considerable weight are required in their construction.

4. Guns are of two kinds, viz. (solid) shot guns, and shell guns. The former are distinguished by the weight of their (solid) shot, and are as follows,—3, 6, 9, 12, 18, 24, 32, 42, 56, and 68-prs., from all of which, solid shot, shells, &c. are projected. The shell guns, viz. the 10 and 8-inch are distinguished by the diameters of their bores, and are not intended to throw solid shot, but hollow shot, shells, &c. These guns were introduced by General Millar, in 1824, for the navy, in imitation of the French Paixhans shell guns; they are merely long iron howitzers.

5. Some guns are also classed as heavy, medium, and light.

6. The following natures of guns, viz. 3, 6, 9, and 12-prs., which are generally employed for field service, are made of bronze or gun-metal; all guns of higher calibre, of cast-iron. 6, 9, and 12-prs. have also been made of cast-iron, but are now only to be found in some few garrisons. The advantages, and defects, &c. of bronze and cast-iron will be noticed when considering the materials employed for the manufacture of ordnance. Rifled ordnance for the service are made of wrought-iron.

**Bored-up guns.** 7. A certain number of iron guns in the service, have been re-bored to a calibre greater than that with which they were originally cast; drawings of these guns are given in Plates of Guns, X. and XV. "The practice of *reaming-out* guns, or boring them up, first took place in the British service, in the year 1830, when about 800 guns, 24-prs. 7 feet 6 inches long, which had been made, according to the construction recommended by Sir W. Congreve, and about as many more guns, also 24-prs., of Sir T. Blomefield's construction, were bored up to 32-prs. for the navy. The practice was afterwards extended to iron guns of all natures, from the 9-pr. to the 32-pr. inclusive, by enlarging the bore of each to the next and, in some cases, to the second higher calibre, and leaving reduced windages. This may be considered as a temporary expedient to increase the weight of metal projected from such guns as were then on hand in this country, at a time when the advantages of large calibred ordnance were not absolutely decided on, and when the government was not prepared to sanction the expense of casting new guns for projecting the heavier natures of shot and shell."<sup>1</sup>

**Shell guns.** 8. There are now in the service one nature of 10-inch gun, and four of 8-inch; those most commonly used are—

Nature.	Length.		Weight. cwt.
	ft.	in.	
10-inch	9	4	87
8-inch	9	0	65
do	8	0	52

A certain number of shell guns are associated with the usual armament of vessels of war, the nature of gun depending upon the class of vessel; these guns are also employed in fortresses, coast batteries, &c.

9. The 8-inch of 52 cwt. was associated with the 24-pr. of 50 cwt. in the first siege trains to the East, in 1854, and is now mounted on a travelling carriage and employed as a siege gun; this gun (by order dated 28th Nov. 1859) is the most suitable piece for the armament of caponnières and flanks of works. The short 8-inch of 50 cwt. was proposed as a substitute for the 68-pr. carrenade, for flanks, interior defences, and for commanding landing places; it is a good gun for ricochet purposes.

**68-prs.** 10. There are two 68-prs. in the service,

Nature.	Length.		Weight. cwt.
	ft.	in.	
68-pr.	10	10	112
do	10	0	95

The first is intended exclusively for land service, being considered too heavy for naval armaments; it is a most powerful gun, and should be used in those positions where the longest

<sup>1</sup> Sir H. Douglas.

ranges are required. The second, which also possesses very great range and accuracy, may be used as a pivot gun for steamers, and men of war, generally.

56-prs.

11. The two natures of 56-prs., viz. heavy and medium, are intended principally for coast batteries; they were constructed by Mr Monk, before the introduction by Colonel Dundas of the 68-pr. guns.

Nature.	Length. ft.	Weight. cwt.
56-pr. ....	11	97
do	10	86

Only a few comparatively of these guns were cast, as their calibre is so very similar to the 68-pr., and they were generally considered deficient in strength; there are still a considerable number in the service.

42-prs.

12. The 42-prs., of which there are several descriptions, varying considerably in length and weight, were intended for the navy. The lighter 42-prs. have been put into block ships, for the defence of the dockyards.

32-prs.

13. Guns of this nature are in general use in the land and naval services; there are no fewer than thirteen descriptions of 32-prs., varying in length and weight to suit the different classes of vessels for which they have been introduced from time to time. The following are generally employed in the land service, viz.—

Nature.	Length. ft. in.	Weight. cwt.
Dundas' 32-pr. ....	9 6	58
Blomefield's do .....	9 6	56
Monk's A. do .....	9 0	50

These pieces possess considerable range and accuracy of fire; the latter was sent to the East in 1855, as a siege gun, and in many respects is a more useful gun than the 24-pr. of 50 cwt. for siege equipments, being equal to it in point of range, with similar weight of metal, but having the advantage of increased calibre; in addition to which, ammunition could on an emergency, be supplied for this gun by the navy, when carrying on joint operations.

24-prs.

14. The 24-pr. is used exclusively for land service, in fortresses and coast batteries, but generally as a siege gun. The most efficient gun of this class is,

Nature.	Length. ft. in.	Weight. cwt.
24-pr. ....	9 6	50

It is a good gun for breaching purposes.

18-prs.

15. 18-prs. may be used with advantage for siege purposes, in those countries where guns of larger calibre could not be transported without great difficulty. These guns (of 38 cwt., length 8 ft.) are also employed as guns of position.



- 12-prs. 16. 12-pr. (bronze) guns of 18 cwt. and 17 calibres in length, are suitable for guns of position.
- 9-prs. 17. 9-prs. (bronze) guns of 18½ cwt. and 17 calibres in length, are considered the best smooth-bored pieces for field batteries, and have also been attached to some troops of Horse Artillery.
- 6-prs. 18. 6-pr. (bronze) guns of 6 cwt. and 17 calibres in length have been principally used by the Horse Artillery; they might also be employed with advantage by the Field Batteries, in countries where, from the nature of the ground, &c. 9-prs. would be too heavy. These guns are also used for Naval Service.
- 3-prs. 19. 3-pr. of 2½ cwt. are for mountainous or difficult countries.

*Rifled Guns.*

Lancaster guns. 20. A few heavy ordnance, rifled upon Lancaster's principle were introduced into the service, in 1854, and employed in the Crimea; they were, however, withdrawn from the service after the war, in 1856. The principle and defects of Lancaster's mode of rifling will be explained hereafter.

Armstrong guns. 21. Some rifled guns of Armstrong's construction are now being introduced into the service; two batteries of 12-prs. (of 6 cwt.) have already done good service in China, and the following calibres are now adopted, viz. 6, 12, 25, 40, and 100-prs. A description of this (breech-loading) gun with its projectile, &c. will be given with those of other rifled ordnance. These guns which are constructed of wrought-iron, are much lighter than any service guns, throwing projectiles of corresponding weight.

100-prs. The 100-prs.

Length.	Weight.
ft.	cwt.
10	80

are intended for the navy or for coast batteries and garrisons when very powerful ordnance are required.

40-prs. The 40-prs.

Length.	Weight.
ft.	cwt.
10	30½

will most probably be employed as siege, garrison, and naval guns, and also for coast batteries.

25-prs. The 25-prs. are of two kinds,

	Length.	Weight.
	ft. in.	cwt.
Land Service	8 0	16½
Sea Service	5 6	12½

the first intended for guns of position, and the second for boat service.

12-prs.	The 12-prs.	Length.	Weight.
		ft.	cwt.
		7	8½
are for field guns, the projectile weighing 12 lbs. for field batteries, and 9 lbs. for Horse Artillery.			
6-prs.	The 6-prs.	Length.	Weight.
		ft.	cwt.
		5	8½
are for mountain service.			

*Mortars.*

22. Mortars are short pieces of ordnance, used to throw shells at high angles (vertical fire), generally 45°, the charge varying with the range required; they are distinguished by the diameters of their bores. Mortars are made of cast-iron or bronze; the former being principally intended for garrisons, battering trains, the navy, &c., and the latter, which are of small calibre, and very light, are chiefly employed in sieges.

Iron mortars.	23.	The iron mortars for land service are,	
		Nature.	Weight,
			cwt.
		13-inch of	36
		10 .....	18
		8 .....	9
	For sea service,		
		13 .....	100
		10 .....	52

These mortars are found most effective in the bombardment of towns, forts, or works of any kind, the shells from them possessing great penetration, in consequence of the high angles at which they are fired; also, the large body of flame liberated on the explosion of these shells, will frequently ignite any combustible material near which they fall, setting fire to buildings, endangering the safety of powder magazines, and creating the most terrible moral effect, especially from the fact, of ordinary parapets affording no secure protection against the nearly vertical descent of the shells.

Bronze mortars.	24. The bronze mortars are	Nature.	Weight.
			cwt.
		5½-inch royal of 1½	
		4¾ . . . . cohorn. . ¾	

They are very useful in the advanced trenches in the attack of fortified places, as they can be moved with great facility to different parts of them, if required; they are not generally placed in batteries, the trenches affording sufficient cover for them against the enemy's fire. These mortars are very annoying to the working parties of the attacking army, when fired upon them by the besieged; they will also be found very useful in the

attack of intrenched posts, on account of their portability, for which reason they can be employed in situations where it would be impossible to move guns. In India, they have been found very effective in the attack of hill forts, stockades, &c.

25. The French, and some other Continental nations, use bronze for-mortars of large calibre.

#### Howitzers.

26. Howitzers resemble guns in form, but are much shorter and lighter in proportion to their calibre, and are, consequently, fired with less charges of powder; shells and case are fired from them, but not solid shot.

These pieces were originally introduced for the purpose of firing shells at low angles, and have constantly been found most useful both in the field and in siege operations during the wars of the last and present centuries. Since, however, the introduction of shell guns<sup>1</sup> their utility has greatly decreased, for the shell gun possesses greater accuracy and range than the howitzer, these being in the present day of greater importance than small weight. The great accuracy at long ranges now obtained by the adoption of rifled small arms and ordnance would put their employment for the future out of the question except for very confined situations where a number may be on the spot.

27. They may be divided into two classes, the heavy howitzers made of cast-iron, and the lighter ones of bronze.

Iron howitzers. 28. There are two natures of iron howitzers, viz.

Nature.	Length. ft.	Weight. cwt.
10-inch. ....	5	42
8-inch. ....	4	22

These howitzers are mounted on travelling carriages, and have been chiefly employed for ricochet fire, but they are also used as guns of position, in battering trains, garrisons, coast batteries, and in those situations where no great range is required. The great advantage derived from the employment of these pieces is that very large shells can be projected from pieces of small weight capable of being transported with ease; their recoil is, however, very great, and consequently, the destructive effects upon their carriages (from the recoil), while but short ranges are obtained from them.

Bronze  
howitzers.

29. There are four natures of bronze howitzers, viz.

Nature.	Length. ft. in.		Weight. cwt.
32-pr. ....	5	3	17·75.
24-pr. ....	4	8·5	12·5
12-pr. ....	3	9	6·5
4½-inch. ....	1	10·6	2·5.

<sup>1</sup> Light shell guns were used in preference to heavy iron howitzers in the siege of Sebastopol, and the Emperor Napoleon substituted a shell gun for his field guns and howitzers shortly after his accession to power.

32-pr.  
howitzers.

30. The 32-pr. howitzer was introduced by Col. Dundas, being intended to accompany the 12-pr. gun in the field; batteries of position are sometimes composed of these howitzers alone.

24-pr. and  
12-pr.  
howitzers.

31. The 24-pr. and 12-pr. howitzers, both of ten calibres in length, were introduced by General Millar, and superseded the old 5½ and 4½-inch howitzers of five calibres; their chief point of difference is an increase of length, the calibres remaining the same. Russia had adopted field howitzers of ten calibres in length, as far back as the seven years' war, these pieces being 8, 12, and 24-prs. The 24 and 12-pr. howitzers have been employed for field service, and associated in batteries with guns of nearly equal weight, in the proportion of two howitzers to four guns; the 24-pr. howitzer accompanying the 9-pr. gun, and the 12-pr. howitzer, the 6-pr. gun. These howitzers have also been used for Naval Service.

Disadvantages  
of employing  
guns and  
howitzers in  
the same  
battery.

32. It is considered by many, that batteries should be composed of either howitzers or guns, but that the two different kinds of ordnance should not be combined in one battery, the effective range of the howitzers being inferior to that of the gun with which it is allied, and the purposes for which the gun and howitzer are respectively employed, being generally speaking, dissimilar (see Art. 38). This point will be again referred to in the Lecture on the application of Artillery.

4½-inch  
howitzers.

33. The 4½-inch howitzer is associated with the 3-pr., for mountain service.

#### *Carronades.*

34. Carronades are short pieces of ordnance, and have less thickness of metal than guns of the same calibre. They were first introduced by the director of the Carron Foundry, in Scotland, and were brought into the service, in 1779. Very beneficial and important effects resulted from their use, since the great advantage which they possess of very reduced windage, was not then extended to other ordnance. This superiority only lasted until the reduction of windage was effected to a certain degree in other guns, when, from their many defects, they were almost rendered obsolete.

Advantages.

35. Their peculiar advantages may be stated, to consist in their capability of projecting shot of large calibre with accuracy to such distances, as vessels of war were supposed to engage at, viz. from 400 to 600 yards, with a great saving of metal, powder, and gun detachment.

Peculiar  
construction.

36. These pieces have no trunnions (see Plate XXX), and are cast with a loop underneath, a bolt passing through which attaches them to their carriages. They have no swell at the muzzle, but an enlargement of the bore or cup, to facilitate the

putting in of the shot, and to save the rigging and hammock nettings on board ship. They have a sight on the reinforce ring, and their chambers are cylindrical, the charge being one-twelfth the shot's weight. They are very unsteady in their recoil, owing to their lightness, and the position of the loop.

Carronades have been constructed of all calibres, from the 6-pr. to the 68-pr., with the exception of the 56-pr.

Tables of  
ordnance in the  
British Service.

37. From the following Table may be seen the respective length, weights, charges, &c. of a selection from the immense number of smooth-bored ordnance in the service, only those in general use being given :—

CAST-IRON ORDNANCE.												
Nature of Ordnance.	Length.	Weight.	Windage.	Calibre.	Charges.				Fire Proof.			
					Shot or Dis- charge Shell.	Improved Shrapnel Shell.	Common Shell.	Saluting.	Charge.	Shot.	Wad.	
10-in. gun	9 4	96	16	10	12 0	8 0	12 0	6 0	20 0	1 hollow	1 stick	
8-in. "	9 0	65	125	8-05	10 0	8 0	10 0	5 0	20 0	1 solid	1 junk	
do "	8 0	52	125	...	8 0	6 0	8 0	5 0	16 0	1 "	1 "	
do "	6 8½	50	125	...	8 0	6 0	8 0	5 0	14 0	1 "	1 "	
68-pr. "	10 10	112	2	8-12	18 0	10 0	10 0	8 0	30 0	1 "	2 "	
do "	10 0	95	2	...	16 0	10 0	10 0	8 0	28 0	1 "	2 "	
56-pr. "	11 0	98	175	7-65	14 0	10 0	10 0	8 0	28 0	1 "	2 "	
do "	10 0	87	175	...	14 0	10 0	10 0	8 0	25 0	1 "	2 "	
32-pr. "	9 6	58	198	6-375	10 0	10 0	10 0	6 0	21½ 0	1 "	2 "	
do "	9 6	56	233	6-41	10 0	10 0	10 0	6 0	21½ 0	1 "	2 "	
do (A) "	9 0	50	198	6-375	8 0	8 0	8 0	5 0	18 0	1 "	1 "	
24-pr. "	9 6	50	211	5-823	8 0	8 0	8 0	5 0	18 0	1 "	2 "	
do "	9 0	48	211	...	8 0	8 0	8 0	5 0	18 0	1 "	2 "	
18-pr. "	9 0	42	193	5-292	6 0	6 0	6 0	4 0	15 0	1 "	2 "	
do "	8 0	38	198	...	6 0	6 0	6 0	4 0	15 0	1 "	2 "	
10-in. how.	5 0	41	16	10	...	...	7 0	4 0	12 0	1 hollow	1 stick	
8-in. "	4 0	21	14	8	3 0	3 0	4 0	3 0	8 0	1 "	1 "	
13-in. mor.	4 4-8	100	16	13	...	...	20 0	...	20 11	{ 1 cylindr of 4½ cwt.	...	
10-in. "	3 9-6	52	16	10	...	...	9 8	...	9 8	1 solid	...	
13-in. "	3 3-6	36	16	13	...	...	9 0	...	9 0	1 "	...	
10-in. "	2 7-5	18	16	10	...	...	4 0	...	4 0	1 "	...	
8-in. "	2 1-2	9	14	8	...	...	2 0	...	2 0	1 "	...	
BRONZE ORDNANCE.												
12-pr. gun	6 6-6	18	1	4-62	4 0	4 0	4 0	3 0	5 0	1 solid	...	
9-pr. "	6 0	13½	1	4-2	2½ 0	2½ 0	...	1½ 0	3½ 0	1 "	...	
6-pr. "	5 0	6	1	3-66	1½ 0	1½ 0	...	1 0	2 0	1 "	...	
3-pr. "	3 0	2½	1	2-91	0 10	...	...	0 10	1 0	1 "	...	
32-pr. how.	5 3	17½	123	6-3	3 0	3 0	3 0	2 0	4 0	1 "	...	
24-pr. "	4 8-6	13	125	5-72	2½ 0	2½ 0	2½ 0	1½ 0	2½ 0	1 "	...	
12-pr. "	3 9-2	6½	126	4-58	1½ 0	1½ 0	1½ 0	1 0	1½ 0	1 "	...	
4½-in. "	1 10-6	2½	0-66	4-52	...	...	0 8	0 4	1 0	1 "	...	
5½-in. mor.	1 3-1	1½	0-25	5-62	...	...	0 7	...	0 7	1 "	...	
4½-in. "	1 0-7	0½	0-66	4-52	...	...	0 6	...	0 5	1 "	...	

The lengths, weights, and other particulars of the Armstrong breech-loading rifled guns at present adopted are contained in the following Table :—

WROUGHT-IRON ORDNANCE.						
Nature.	Length.	Weight.	Calibre.	No. of Grooves*	Twist of Rifling.	Charge.
	ft. in.	cwt.	in.			lbs. oz.
100-pr. ....	10 0	80	7	76	1 turn in 35 cal.	12 0
40-pr. ....	10 0	30½	4-75	56	do 36½ "	5 0
26-pr. (L. S.)	8 0	16½	3-75	44	do 38 "	3 3
26-pr. (S. S.)	5 6	12½	3-75	44	do do "	3 3
12-pr. ....	7 0	8½	3	28	do do "	1 8
6-pr. ....	5 0	3½	2-5	22	do do "	0 12

\* The dimensions of the grooves are the same for all these guns, the number increasing therefore with the calibre.

*French Guns.*

12-pr. shell  
gun.

38. The pieces employed by the French for field artillery, until the introduction of the 12-pr. shell gun (canon-obusier), were the

12-pr. gun.

8-pr. do.

Howitzer of 16 centimetres (6 in.).

do. 15 do. (24-pr.).

In order to simplify the service and equipment of field artillery, the 12-pr. shell gun was proposed as a substitute for these four pieces by the Emperor Louis Napoleon, when President of the Republic, and was subsequently adopted into the French service. The chief advantages of the new system were,—That there was only one gun carriage, one description of ordnance, and 4 projectiles; it therefore abolished one gun carriage, 3 natures of ordnance, and 9 projectiles.

With regard to the superiority of this system over that formerly employed, the following extracts are here given from a small work entitled, *The Emperor Napoleon's New System of Field Artillery*.<sup>1</sup>

“The advantage of range, of accuracy, and of penetration, which the 12-pr. has over guns of smaller calibre will give to our batteries a decided superiority. Two of our cannon can oppose without disadvantage, one 12-pr. and one 8-pr. gun of the present system; but there is in the trains of artillery of the present day only one 12-pr. for five 8 prs.; and if we oppose to these six pieces, six of our cannon, we shall have the advantage.

“Our superiority becomes much greater if we consider six batteries on both sides; for we shall throw *thirty-six* 12-pr. shot whilst the present system can throw only *four* 12-pr. shot, *twenty* 8-pr. shot, two shells of 16°, and ten shells of 15°, these last projectiles having much less accuracy.

“There is an essential advantage in the proposed system, to which we call the attention of all scientific men, viz. the power of firing at will, either round shot or shells, from all the pieces, for it has the effect of trebling the actual power of a battery as regards hollow projectiles, or of increasing by one-third the effect as regards solid shot. At present a battery composed of four guns and two howitzers does one of two things; it either makes use alternately of the four first and the two second, or it fires these pieces together. In the first case, the effect of its fire is considerably reduced; in the second, it is acknowledged that one of the two is sacrificed to the other.

Rifled pieces.

39. Rifled ordnance were introduced into the French Service just previous to the commencement of the late Italian war of 1859, and aiming at the greatest practical simplicity, the French

<sup>1</sup> Edited by Capt. Favé, and translated into English, by Capt. W. H. Cox, R.A.

government adopted only one nature of gun for field service, and one for siege purposes, both made of bronze. The calibre of the field gun is about 3.36 or rather less than that of a 6-pr., the weight of the piece is about 5 or 6 cwt., and the charge about 1 lb., the elongated projectile (shell) weighing about 9 lbs. The calibre of the siege gun is that of a 12-pr., its charge being about 2½ lbs. The French rifled cannon are muzzle loading, and those first introduced had 2 or 3 grooves, but the field pieces used in Italy had 6 grooves, their inclination being about 1 turn in 59 inches. The form of the projectile will be explained in the Lecture on Rifled Ordnance. A number of heavy cast-iron guns, rifled with 2 grooves, have been placed on board French ships of war; these, unless strengthened, could be used but with very small charges.

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## ARTILLERY CARRIAGES.

1. THE various kinds of artillery carriages used in the service, may be classed as follows:—

- (1) Field carriages.
- (2) Carriages for guns of position.
- (3) Siege carriages.
- (4) Garrison do. (including those for coast defences).
- (5) Carriages for the transport of heavy ordnance, their carriages, &c.
- (6) Naval gun carriages.

2. Before describing each class separately, the construction of the carriages composing the class, and the special purposes for which they are intended, it is necessary to consider the general principles of construction, common to all artillery carriages (whether gun carriages or for draught), and also the effect of the discharge of a piece upon its carriage.

### *General Principles of Construction of Artillery Carriages.*

General principles to be observed in the construction of artillery carriages.

3. An artillery carriage should be of the simplest construction, so as to be capable of being easily repaired; it should have sufficient mobility for its peculiar service, and its centre of gravity should be so placed that it may not be liable to upset on passing over rough or uneven ground.

There should be as few varieties of carriages as possible, and the several parts of the same description of carriage should correspond, and be made of exactly the same pattern. Moreover, it is desirable, as far as possible, to assimilate the general constructions, modes of draught, size of wheels, &c. of those carriages which are intended to act together, as for instance, those of a Field Battery; the parts also designed to perform the same offices in carriages of different constructions should have the same form and dimensions when possible. By attention to these points, the manufacture will be more rapid and correct, the equipment of stores will be simplified, and the different carriages can be readily repaired by exchange of parts, which will be found very important on service.

4. An artillery carriage generally consists of two parts,<sup>1</sup> a body and a limber; the former carries the whole or greater part of the load,<sup>2</sup> and the latter, which carries or supports a portion

<sup>1</sup> The exceptions are garrison and naval carriages, which are not adapted for transporting their guns, trench carts, &c.

<sup>2</sup> The body in our service carries about two-thirds, and the limber one-third of the load.



of the load, serves as a means whereby motion is communicated in travelling to the first, and forms with it a four-wheeled carriage, suitable for the requisite purposes of transport or manœuvring. The manner in which the two parts are connected, varies according to the purpose for which the carriage is intended.

5. When a comparatively small weight, and great mobility are required, as in most of the carriages of field artillery, the fore part of the body hooks up to a crooked pintail placed at the back of the limber; but as this pintail could not offer a very great resistance, the weight of the carriage must bear principally upon the rear axletree. (Fig. 1, Plate 11).

6. When the weight is very great, as in siege carriages, &c., it must be distributed throughout the whole length of the body (trail); for should the load be placed too far back over the rear axletree, it would, in going up steep inclines, and over rough ground, cause the point of the trail to be jerked upwards with violence, the gun tending to fall over to the rear. In this case, the point of the trail will be very heavy, and it is therefore made to rest upon a straight pintail, placed above the front axletree. (Fig. 2, Plate 11).

7. The construction of the body of the carriage and limber will depend upon the weight and nature of the load; this will be explained in describing the construction of each kind of carriage.

Points to be considered with regard to the draught of the carriage.

8. The following points must be attended to, in order to decrease, as far as possible, the work necessary for the draught of the carriage :—

- (1) The wheels must have all the height they can be allowed.
- (2) The mean diameter of the axletree arms must be reduced to a minimum, consistent with the necessary strength.
- (3) The axletree arms and boxes of the wheels must be made of materials between which there will be but slight friction.
- (4) The angle of traction must be that most favourable to the motive power.

9. With regard to the first point, it is generally considered that the height of wheel for carriages intended to move with rapidity or for general purposes, should not exceed 5 feet, as the weight of the wheel would be increased by greater dimensions, and the load would be raised to a height that would render the carriage liable to upset, unless its width was increased, or its construction otherwise altered. A diameter of 5 feet is consequently adopted for the wheels of all carriages in our field artillery, as well as for the greater number of those for siege carriages. With carriages that are required to move but slowly,

and over very rough ground, a greater diameter may sometimes be employed with advantage, as with the hind wheels of sling wagons (which are 7 feet), the extra height being also necessary with these carriages in order to raise the gun or mortar, conveyed underneath, sufficiently above the surface of the ground.

10. The axletree being composed of forged iron, a strong material, can be made with a small diameter, and thus the friction of the arm against the pipe-box will act with a very small lever arm, compared to the radius of the wheel, and the size of the nave is diminished, as well as the weight of the wheel.<sup>1</sup>

11. The axletree arms in our service have a portion of steel let into them underneath, at those parts bearing upon the pipe-box (about 3 inches from each end of the box), which is made of cast-iron; these boxes were formerly made of brass, but iron is found to last longer, and is much cheaper. We, therefore, have iron working on steel, between which there is but slight friction, particularly when the proper unguents are employed.

12. If the plane upon which a carriage had to run was a perfectly smooth surface, the most advantageous direction for traction would, doubtless, be parallel to the plane; but as artillery carriages may have to travel on the worst description of roads, or over very rough ground, where there are stones, ruts, and other obstacles to be constantly overcome, the angle of traction must be slightly inclined upwards, as the vertical component of the pull will then assist the wheels to surmount such obstacles; the weight being transferred to the shoulders of the horse, increasing the pressure of his feet upon the ground, thus giving him a firmer hold, and enabling him to exert with ease a stronger pull, while the resistance against which he contends is at the same time diminished. (Fig. 1, Plate 5).

In the third volume of the *Mathematical Course*, p. 237, it is stated, "That to produce the best effect, the tangent of the inclination of the traces should be equal to the ratio of the traction to the load, or

$$\tan a = \frac{T}{W} \text{ nearly.}''$$

In Begbie's translation of an *Essay upon Gun Carriages*, by Miguet and Bergery, we find 12° given as "the angle which combines every advantage," and "if by adopting it, we do not obtain to the letter, the maximum of effect, we may at least be certain, that it is not very far from it." This angle was deduced from some experiments carried on at Metz, in 1816, by General

<sup>1</sup> This decrease of the axletree arms is by some considered not to facilitate the draught, but that for heavy carriages and slow draught large axletree arms should be employed.

Berge. As, however, different animals exert their strength most advantageously in different directions, practice alone can determine the proper position for the shafts, which, however, should always be arranged so that the traces may be slightly inclined upwards, when attached to the collar of a horse of the average size employed. This angle in our service is about  $6\frac{1}{4}^{\circ}$ .

*Number of Horses required for Artillery Carriages.*

Force of traction.

13. In order to determine the number of horses that will be required for the draught of any carriage, it is necessary to ascertain the "force of traction," which a horse of average strength is capable of exerting. It is not the momentary, but the continued effort, which it is necessary to know, the latter being of course much less than the former. This effort will depend upon the rate or speed of travelling, the time for which the force must be exerted, and the nature of the ground over which the carriage will have to travel.

Work of a horse in draught.

14. It is generally considered that a horse moving at a rate of about three miles an hour, can exert a force of 125 lbs. for 8 or 10 hours; if the rate be 7 miles an hour, the draught should be reduced to about 90 lbs., and be continued for a shorter time, viz. 5 or 6 hours; and should greater speed be required, the horse ought not to have to draw with a force exceeding 50 or 60 lbs., and for a period of from 1 to 3 hours, depending upon the speed.

15. If a team of horses be harnessed to a carriage, the effective power exerted by the whole team will not be increased in the same ratio as the number of horses, but as this number is increased, so will the effective power of each horse be decreased; this arises from the great difficulty of making all the horses of the team exert their proper amount of force at the same instant.

Number of horses required.

16. It is considered by the French,<sup>1</sup> that no more than six horses should be employed for the draught of any carriage that may be required to move with rapidity, and to traverse every description of country. For carriages of the greatest weight in our service (the 32-pr. or 8-in. siege gun), it is found advisable not to employ more than 12 horses.<sup>2</sup>

17. Artillery carriages having no springs, and being usually obliged to travel over very rough ground, require a greater number of horses than would be necessary for ordinary carriages of similar weights; and this is the more needful, in consequence of their being liable to lose some of the number in action, or

<sup>1</sup> Mignet's and Bergery's Essay upon Gun Carriages, translated by Begbie.

<sup>2</sup> This remark applies only to organised teams; a sling wagon with a heavy gun is drawn by a number of pairs of horses, frequently more than six pairs.

from the hardships to which horses are always exposed in a campaign.

Number of horses to a carriage depends upon the required rapidity of movement.

18. As the force of traction is diminished by rapidity of movement, it has been considered desirable to divide teams of artillery horses into,

- (1) Those of Horse Artillery.
- (2) ———Field Batteries.
- (3) ———Heavy Ordnance.

Horse Artillery having generally to act with cavalry, are frequently obliged to move with great rapidity, or at a gallop. Field Batteries being attached to infantry, their rate of movement would rarely exceed an ordinary trot. Heavy Ordnance are never required to manœuvre with troops, and from their great weights, the rate of travelling is confined to a walk.

The load which each horse should be required to draw, is given by Decker, thus,

For Horse Artillery ..... 500 lbs.  
„ Foot do. .... 650 „  
„ Siege do. .... 750 „

These, however, he adds, are less than what would actually be the case on service.

In Miguet's and Bergery's *Essay upon Gun Carriages*, the following is given:—

For teams of Light Field Batteries..... 743·281 lbs.  
————Field Parks do. .... 878·425 „  
————Siege Train do. ... 1013·576 „

19. The following Table will shew the load that each horse has to draw in heavy and light teams in our service:—

Nature of Carriage.	Total weight of gun, carriage, ammunition, &c.	Number of horses.	Weight each horse has to draw
24 or 32-pr. gun carriage.	cwt. 84	12	cwt. 7.
18-pr. do.	66	12	5·6
12-pr. do.	44	8	5·5
9-pr. do.	38	8	4·75
Light 6-pr. do.	28	6	4·6
9-pr. ammunition wagon.	34	6	5·6
12-pr. Armstrong gun carriage	37	8	4·63
do. ammunition wagon	41	6	6·83

From this Table it appears that each horse has to draw,<sup>1</sup>

In a team for Horse Artillery, about... 4½ cwt.  
————Field Batteries „ .... 4¾ „  
————Heavy Ordnance „ 5½ to 7 „

For the ammunition wagon the draught is however much heavier, each horse with the 9-pr. ammunition wagon being required to draw 5·6 cwt., and with the Armstrong 6·83 cwt.

<sup>1</sup> Independently of the weight which each horse has to draw, one half of the horses will have in addition the weight of their drivers to carry.

In an experiment at Metz, in 1825, with a light field gun carriage, it was found that, at a walk over fine turf, the ratio of the traction to the load was one-twentieth, and over recently ploughed land, one-tenth.

Applying this latter value to our 9-pr. field carriage, each horse would have to exert a force of .475 cwt. or 53.2 lbs.; with a horse artillery carriage (light 6-pr.), this force would be .46 cwt. or 51.5 lbs. These apply merely to level ground.

#### *Mode of Draught.*

20. Shafts are employed in the British Service, in preference to the pole for the draught of artillery carriages.

21. For field carriages, and those for light guns of position, double draught is employed, the off-horse being placed in the shaft; for siege carriages, and those of heavy guns of position, four horses are harnessed abreast, there being two pairs of shafts, one for each of the inside horses; shafts for single draught are supplied to the mountain service artillery carriages.

22. The chief advantage obtained by the use of shafts, instead of a pole, for field carriages is, that the carriage is more under control for manœuvring or turning; they have the following disadvantage, viz. that in stopping the carriage, or in going down steep hills, the shaft-horse will have to bear the greater part of the weight of the carriage, and very powerful horses will therefore be required. The pole is generally employed on the Continent, as the draught is supposed to be more equally distributed between the horses. The method of attaching the shafts and traces will be explained in the notes on the Manufacture of Carriages.

#### *Effect of the Discharge of a Gun upon its Carriage.*

23. When a gun is discharged, as the elastic gas exerts an equal pressure in every direction, a force will be applied at the bottom of the bore, and in the direction of the axis, equal to that which acts upon the projectile,<sup>1</sup> and the gun, if free to move, would be forced backwards in a direction opposite to that in which the projectile is thrown.

If the gun be placed upon a carriage, its momentum acting upon the carriage, causes the recoil, always observed, when a piece is discharged, and also certain destructive shocks or strains upon the carriage.

24. Should the carriage rest upon a horizontal plane, and the gun be laid point blank, the axis of the trunnions not being below that of the piece (Fig. 2, Plate 5); then, the momentum

<sup>1</sup> Not strictly correct, see Boxer, p. 35.

of the gun will be expended in forcing the carriage to the rear in the direction of the axis of the piece, and strains will, consequently, be exerted upon the trunnion holes, and from them be transferred to the axletree arms; also, since the centre of gravity  $G$ , of the system (gun and carriage) is below the axis of the piece in which direction the force of the powder acts, the whole will have a tendency to rotate round the axletree, which, being checked by the point of the trail touching the ground, will cause the system to rotate round this point, forcing it into the ground, the wheels being at the same time lifted up.

Effect upon the carriage when the gun is elevated, or when the ground or plane slopes upwards to the rear.

25. Should, however, the gun be fired at a considerable angle of elevation, the momentum communicated to it will give a shock vertically down upon the carriage, causing destructive effects upon various parts of it, as well as a backward shock of somewhat less amount than in the former case. This destructive effect increases with the angle of elevation.

In Fig 3, Plate 5, if  $AB$  be taken to represent the force of the gas, acting at the bottom of the bore,  $AC$  will represent the destructive effect exerted normally upon the carriage, and  $CB$  that which urges the carriage to the rear.

If  $AC$  or the angle of elevation be considerable, the wheels and trail will both be forced into the ground, and divide the shock acting vertically upon the carriage between them.

26. In each of the above cases, the gun and carriage not being rigidly connected together, when a resistance is suddenly offered to the trail by the ground, the gun will continue to rotate round the fixed axis of the trunnions, until stopped by the head of the elevating screw, upon which, consequently, a considerable blow will be given.

27. It is also evident, that should the gun carriage be standing upon a plane, inclined upwards to the rear, destructive effect will be exerted upon the carriage and ground or platform, according to the inclination of the plane.

Effect upon the carriage from the axis of trunnions being below that of the piece.

28. In our service, the axis of the trunnions of a smooth-bored gun is below that of the piece, and two parallel forces may therefore be considered to be acting upon the gun, one of which is the pressure of the elastic gas, applied at the centre point of the bottom of the bore, and in the direction of the axis; the other, the re-action of the trunnion holes in the opposite direction; there will, consequently arise, a tendency to rotation about the centre of gravity of the gun, which will cause impulse to be exerted on the head of the elevating screw, and on the capsquares. In Fig. 4, Plate 5, the gun is supposed to be resting on its carriage, on a horizontal plane, and laid point blank, or with its axis parallel to the plane.

Let  $P$  = impulse on elevating screw,  
 $S$  = do. capsquares,  
 $k$  = horizontal distance of axis of trunnions from centre  
of gravity of gun,  
 $l$  = horizontal distance of elevating screw from centre of  
gravity of gun.

The centre of gravity of the piece being in rear of the trunnions, the force exerted at  $S$  will be in the opposite direction to that at  $P$ . When the two forces, first mentioned, act upon the gun, the direction and position of the forces being represented by the horizontal arrows, there will be a tendency to rotate round the point  $G$ ; and this tendency will cause certain impulses to be given on the top of the elevating screw, and on the capsquares, the direction and position of which are represented by the vertical arrows.

Since the effect produced upon the centre of gravity will be the same as if they were applied directly at this centre; then, in the case in which the centre of gravity has no vertical motion, these impulses will be equal, or  $P = S$ .

These impulses are, in fact, the effect of pressures, and the time for which these pressures act being equal, these pressures themselves are also equal; but their destructive effects will be measured by the products of the pressures, and the space through which the points, where they act, are moved; these spaces are proportional to their distance from the centre of gravity, and the destructive effects will likewise be in the same proportion, or as  $l$  to  $k$ .

Should the resistance to motion be greater at the elevating screw than at the trunnions, which would probably be the case on hard ground, or on a platform, the impulse on the elevating screw will be greater than that on the capsquares; in this case, the system (gun and carriage) will have a tendency to rotate round the point of the trail from this cause, in addition to that arising from the general rotation of the whole system round its centre of gravity.

If the ground be very soft, the system would have a tendency to rotate round the axletree, and the pressure on the elevating screw would therefore be diminished, and that on the capsquares increased.

29. These remarks will shew in what way the resistance of the plane, upon which the gun carriage is resting, to the rotation of the trail, will influence the effect upon the carriage.

If the plane be very hard, or should it have a considerable upward inclination to the rear, then will the destructive effect be very great on the trail, as well as on that part of the carriage to which the elevating screw is attached. The part of the trail

most likely to be injured is just above the trail plate, and this is where attention should be directed, the charge being lessened if the action be too great.

How the impulse on the elevating screw is influenced by the position of the trunnions.

30. The manner in which the position of the trunnions of a piece of ordnance will influence the impulse on the elevating screw may be shewn as follows. (Fig. 5, Plate 5).

Let  $P$  = force of gas,

$R$  = re-action of elevating screw,

$a$  = distance from the centre of trunnions to axis of bore,

$b$  = distance from centre of trunnions to elevating screw.

Taking moments about  $C$ ,

$$P \times a = R \times b,$$

$$R = \frac{a \cdot P}{b}.$$

Consequently, "The impulse on the elevating screw increases directly as ( $a$ ), or distance from centre of trunnions to axis of bore, and inversely, as ( $b$ ), or distance from centre of trunnions to elevating screw."

Principles to be observed in order to lessen the destructive effect upon a gun carriage.

31. In order to lessen as much as possible the destructive effect upon a gun carriage from the discharge of the piece, the following principles should be observed :—

(1) The weight of the piece must be at a maximum, with due regard to mobility, as the velocity of recoil of the gun which acts upon the carriage will thus be diminished.

(2) The weight of the carriage must be at a minimum, consistent with the requisite strength, as its inertia will then be more readily overcome; and, consequently, a less amount of the force of recoil will be expended upon it.

(3) The centre of gravity of the system (gun and carriage) must be as near to the axis of the bore of the piece, and as far as possible from the point of support of the trail, in order to decrease the tendency to rotation.

(4) The wheels must be as light as is consistent with strength, in order {for the same reason as in (2)}, to save the axletree and breast of the carriage.



## GENERAL DESCRIPTION

or

# ARTILLERY CARRIAGES.

### *Field Carriages.*

1. This class embraces all carriages for the transport and service of guns, and the conveyance of ammunition, stores, &c. belonging to the various kinds of batteries for field or mountain service.

2. Batteries for field service have generally been composed of

9-pr. guns, with 24-pr. howitzers,  
or 6-pr. do. 12-pr. do ;

the former for Field Batteries, and the latter for Horse Artillery; Horse Artillery have, however, sometimes been armed with 9-pr. guns, and 24-pr. howitzers.

For mountain service,—3-pr. guns with 4½-in. howitzers, are employed.

12-pr. Armstrong rifled guns for field service, and 6-pr. Armstrong rifled guns for mountain service, are now replacing the above.

3. The gun carriages of a battery are required to accompany the troops, either infantry or cavalry, according to the nature of battery, in all their principal movements; it is therefore necessary that they should possess great mobility, and have a much stronger construction than the other carriages of a battery, which merely convey the ammunition, stores, &c. in consequence of the strains exerted upon them by the discharge of the piece, or when moving rapidly over rough ground, and also from their being constantly exposed to the fire of the enemy.

4. The construction of a gun carriage differs according to the nature of the piece for which it is intended; but all the other carriages of a battery, such as the ammunition wagon, forge, &c. whether for Field Batteries or Horse Artillery, are similar in general construction, the only difference being in the interior arrangement of the boxes which contain the ammunition or stores.

5. The gun carriage and ammunition wagon are the two most important carriages in a battery; for although in our service, the latter is not supposed to accompany the gun in action, but must be kept as much as possible out of the range of projectiles by remaining at some distance from the guns, or

taking advantage of cover &c., yet the effective fire of the battery for any length of time will depend upon the wagons being sufficiently near to make use of their ammunition when required, and the construction of the wagon must therefore allow of its passing over any ground accessible to the gun carriage. These two carriages will be considered in the first instance.

**Gun carriages.** 6. The construction of a field gun carriage will depend upon the calibre and charge as well as on the nature and weight of the piece, both with regard to its peculiar action when fired, and its requisite mobility.

7. The general principles to be carried out in the construction of a gun carriage, with regard to the injurious action of the gun upon it when discharged, have been already noticed; the following conditions must also be fulfilled in its construction, in order to ensure the efficient service of the piece in the field:—

(1) The construction of the carriage, and the manner in which it is attached to the limber, should allow of its moving with rapidity, of its turning readily, and of its being easily unlimbered or limbered up.

(2) The height of the carriage should be such as to admit of the gun being loaded with ease.

(3) It must have a simple and strong elevating screw, or other means of giving elevation or depression to the piece; also, the traversing handspike must be attached to, or detached from, the trail without difficulty.

(4) The limber boxes must contain such a quantity of ammunition that the gun may not be too dependent upon the ammunition wagon.

These conditions are carried out in the service gun carriages.

8. The gun carriage (Plate 6) is composed of a trail, and two small brackets, one attached to one side of the trail, and projecting slightly above it. The trunnion holes are cut in these brackets; there is only one set, or pair, in the carriage for field service, as it is necessary that the piece should occupy the same position both in travelling and firing, in order that it may be rapidly brought into action. The trunnion holes are placed far back on the carriage, over the rear of the axletree, this position having been found most advantageous with regard to the least amount of strain upon the carriage from the action of the piece when fired; the point of the trail is also rendered very light by thus placing them, so that it can be lifted without difficulty in limbering up, or unlimbering.

The inclination of the trail to the ground has a tendency to check the recoil, but the less so as the angle it makes with the ground becomes more acute; the decrease of this angle must,

however, have its limits, as a great length of trail would render the carriage heavy and unmanageable. The trail of a field gun carriage usually stands at an angle of 21° with the ground.

9. The introduction of the block trail, in 1807, has lessened the weight of the carriage, and also given greater facility for manœuvring, the wheels being enabled to lock very close. A bracket trail, similar to those for siege carriages, was used previously for field gun carriages.

10. The howitzer carriages are, for reasons before stated (Arts. 30, 31, Lecture IV.), made stronger, and therefore heavier than the gun carriages; the ratio of the weight of the piece to that of its carriage is shewn in the following Table, assuming the weight of the piece to be unity :—

Nature.	Weight of piece.	Weight of body of carriage.	Ratio.
9-pr. gun. ....	cwt. 13½	cwt. 7½	·574
24-pr. howitzer .....	12½	8½	·66
6-pr. gun. ....	6	5½	·958
12-pr. howitzer.....	6½	6½	·96

11. The field gun carriage now adopted into the service for the 12-pr. Armstrong gun (Plate 7) is of simpler and less expensive construction than that originally used in experimental practice with similar pieces. It has no recoil slide, and its general form is like that of the ordinary service field gun-carriage with a block trail; it has in addition a screw (*aa*, Fig. 2) turned by a handle (*b*) which is connected by a bar (*c*) with moveable trunnion holes, so that a horizontal motion round a centre between them may be given to the trunnions of the piece, thus allowing for minute alterations in pointing the gun.

Limber.

12. The limber (Fig. 1, Plate 11) consists merely of a framework of wood, placed upon wheels of equal height with those of the gun carriage, and carrying two boxes for the ammunition, &c. to be conveyed with the gun. The trail of the gun carriage hooks up to a crooked pintail at the back of the limber, and when the two (gun carriage and limber) are thus attached or “limbered up,” as it is called, they form a four-wheel carriage suitable for travelling; when unlimbered, the gun carriage rests upon three points, viz. the trail and two wheels, which ensures its steadiness, and enables it to be readily laid. The limber has a splinter bar to which the traces of the horses are attached, and the shafts can be arranged for single, double, or treble draught.

Ammunition wagon.

13. The ammunition wagon (Fig. 1, Plate 11) consists of a body and limber, the latter being identical with that of the gun,

and can be substituted for it if necessary. The body of the wagon is composed of a framework of wood, having a perch passing down the middle, the end of which, like that of the trail of the gun carriage, hooks up to a crooked pintail behind the limber. Upon the body are carried two boxes for ammunition, which are moveable, and can be taken from the carriage, and packed in store if necessary; two men can be carried on each of these boxes, as well as two upon the limber boxes (one on each).

14. The boxes must be so constructed that the ammunition within shall be preserved from moisture of any kind, and that it shall not suffer derangement in passing over rough ground, as otherwise, it might be liable to explode or become unserviceable; moreover, the ammunition must be packed in such a manner in the boxes, that it can be easily taken out when required.<sup>1</sup>

15. All ammunition wagons carry a spare wheel, which is placed on a wooden axletree attached to the perch; the French carry it behind the carriage, so that it can be removed without unlimbering the wagon, and this arrangement has been adopted with the wagons for some of the Armstrong gun batteries.

16. There is but one description of ammunition wagon, the only variation for the different batteries being in the dimensions and interior arrangement of the boxes, which depend on the nature and bulk of the ammunition.

The various  
carriages which  
accompany a  
field battery.

17. The other carriages of a battery would, if possible, be kept entirely out of action, but as they might be required under peculiar circumstances (for instance, in rejoining their batteries) to move with rapidity, and for the sake of simplicity in the material, their general construction should assimilate as much as possible to those of the gun carriage and ammunition wagon. The rocket carriage may frequently be required to keep close to the battery.

18. These carriages are,

The store limber wagon,  
Spare gun carriage,  
Forge wagon,  
Rocket carriage,  
Store cart,  
Medicine cart,  
Forge wagon.

All these carriages have wheels of equal height, viz. 5 feet, and take the same axletrees as the gun carriages of the battery to which they belong, except the forage wagon, which has 4 ft. 2 in. wheels, and light axles.

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<sup>1</sup> In the limber of the 12-pr. Armstrong gun the projectiles are arranged in a very simple manner round the powder, and the fuses and tubes are contained in tin cases, which fit into a middle box between the limber boxes.

- Store limber wagon.** 19. The store limber wagon consists of a body and limber, and is employed to carry the various stores of a field battery, such as the collar makers', wheelers', farriers' stores, &c.
- Spare gun carriage.** 20. The spare gun carriage is merely an ordinary gun carriage, fitted up so as to carry four axletrees, the iron work for a spare gun carriage, a pair of shafts, two sponges, one wadhook, and other spare articles for the battery.
- Forge wagon.** 21. The forge wagon consists of the body of an ammunition wagon, carrying a moveable frame for the bellows, hearth, anvil, &c. and the limber, in which the necessary tools are conveyed.
- Rocket carriage.** 22. The rocket carriage consists of a body and limber, the latter similar to that of the gun carriage. The body is composed of a large case in the centre of which the rocket sticks are carried, and to which the tube is attached in travelling. There is a box on each side of this case in which the rockets are placed vertically, with their heads downwards. The body has a perch, and hooks up to the crooked pintail of the limber.
- Store cart.** 23. The store cart carries the company's books, officers' stores, &c.; the medicine cart and forage wagon are used for the purposes suggested by their names.
- Hospital cart.** 24. There is also a covered hospital cart attached to each battery, for the conveyance of sick and wounded men and medical stores.
- Sleighs.** 25. Sleighs are sometimes employed in Canada, to convey guns and ammunition during the winter; one sleigh carries the gun, and two others the boxes of the limber and wagon.
- Mountain service carriages.** 26. Artillery for mountain service with ammunition, stores, &c. are in our service conveyed on the backs of mules, the only carriages therefore that are required for such a battery are those for the guns and howitzers; these carriages are made on similar principles to those of ordinary field artillery, but are not provided with limbers, as they are not required to travel, the gun carriages being themselves conveyed on mules; the carriages are, however, furnished with a pair of shafts for single draught, which can be attached to the trail.

*Carriages for Guns of Position.*

27. The second class of carriages are those intended for guns of position, and are of two kinds; the first for 18-pr. iron guns; the second for 12-pr. guns (bronze), and 32-pr. howitzers. 8-in. howitzers are sometimes employed as pieces of position, but the general construction of their carriages is similar to those of 10-inch howitzers, and will be explained when considering siege carriages.

28. Until lately, the 18-pr. gun carriage was similar to that of a siege carriage, having a bracket trail and siege limber. A block trail carriage (Plate 8) has been introduced<sup>1</sup> for the 18-pr. gun, similar in general construction to that of a field gun carriage, but necessarily much stronger and heavier; it possesses the following advantages over the old bracket carriage, viz. (1) That the limber is similar to that of a field carriage, and carries 24 rounds of ammunition, none being carried by the old limber. (2) That it can lock round much closer, and does not therefore require much space for turning, the old limber having low wheels (8 ft. 10 in.) to effect this purpose. The wheels of the carriage (gun carriage and limber) are thus of one height, viz. 5 ft., those of the gun carriage being, however, of greater strength and weight than the limber wheels, which are similar to the heavy wheel for field guns.

29. These carriages have two sets of trunnion holes, viz. the firing and travelling holes; the piece rests in the former when in action, but is removed into the latter if required to travel any distance; the weight of the gun being thus more equally distributed between the wheels, and the end of the trail kept down upon the pintail in going up hill, or over obstacles.

30. The carriages for the 12-pr. gun and 32-pr. howitzer, are similar in general construction to those of field gun carriages, only they are provided with two sets of trunnion holes, and the trails hook up to a straight pintail;—if more of these carriages were now made, the crooked pintail would no doubt be adopted. There are three boxes on the limber, instead of two, as with field carriages, it being necessary to have a small centre one to allow room for the straight pintail at the back;—with a crooked pintail, only two limber boxes would be required.

#### *Siege Carriages.*

31. The third class of carriages are those intended for heavy guns and howitzers, employed in the attack of fortresses. These carriages do not require the same mobility as field carriages, or those for guns of position, but must be capable of travelling over rough roads and ground presenting considerable obstacles, at a slow pace. These carriages require great strength, as the pieces mounted upon them are generally fired with large charges of powder.

32. The following principles must be carried out in the construction of a siege carriage, in order that the working of the piece may be effectively performed :—

(1) There should be only one description of carriage, both for firing and transport; this is very important, for it is desirable to

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<sup>1</sup> Proposed by Major Clerk, R.A.

have as few kinds of carriages, as possible, in a siege train, and great inconvenience would be caused by having to shift the piece from one carriage to another under fire.

(2) It is generally considered that an elevation or depression of  $12^{\circ}$  should be allowed to the gun by the construction of the carriage.

(3) The carriage must raise the piece, as high as is consistent with its effective service, in order that the sill of the embrasure may be of corresponding height, by which the parapet will be strengthened, and more cover obtained.

33. The following pieces are mounted on siege or travelling carriages :—

8-in. (52 cwt. and 50 cwt.),  
Monk's A, 32-pr. (50 cwt.),  
24-pr. (50 cwt.)

Bracket carriages have been hitherto used, but by a recent order, block-trails similar in construction to that for the 18-pr. gun (Art. 28) are now adopted.

Bracket  
gun carriage.

34. The body of the bracket carriage consists of two brackets, connected together by three transoms, the trail thus formed being termed a bracket trail (Plate 9).

35. The brackets are of the same form and dimensions for all these pieces, but the length of the transoms which regulate the width of the carriage, varies according to the nature of the gun. The wheels for these carriages are 5 ft. in diameter, and are very strong. There are two sets of trunnion holes.

Limber.

36. The limber consists of a framework, which carries no ammunition boxes, as the straight pintail upon which the trail rests is placed upon the top of the axletree bed (Fig. 2, Plate 11). A part of the weight of the brackets is taken by a sweep bar, which also serves to keep the limber framework horizontal. The limber wheels are made lower than those of the body of the carriage, in order that the carriage may be able to reverse in a small space. The draught of the carriage is not taken by the pintail eye, but by a draught chain, which connects the axletree of the gun with that of the limber.

Howitzer  
carriage.

37. The howitzers mounted on siege carriages are the 8 and 10-in. These carriages require a stronger, and consequently, rather heavier construction than the gun carriages, for reasons before explained. (Plate 10).

38. The body of the carriage is composed of a perch trail, with two short brackets; the perch limbering up to a straight pintail on the top of the limber.

These carriages have only one set of trunnion holes, as it

would be undesirable to shift the howitzer far back on the carriage, the perch not being of very great strength. Underneath the points of the brackets is a wooden axletree carrying two trucks of iron, for the purpose of keeping the perch off the ground, and to facilitate the running up of the carriage. In order to check the recoil, which is very great, two friction levers are employed; one end of the lever is attached to the front of each bracket, and a part of the lever is hollowed out so as to fit over the nave of the wheel; the lever is compressed tightly on to the nave by bolting the other end down to the rear of the bracket, the friction thus produced reducing the extent of the recoil very considerably. The small trucks can also be made to wedge themselves by a very simple contrivance; this, however, is seldom necessary.

45° elevation can be given, if required, to the 8-in. howitzer by removing the bed through which the elevating screw passes.

39. The limber is similar to that of the gun carriage, but the wheels can lock closer in consequence of the perch having considerably less width than the bracket trail.

Common  
ground  
platforms.

40. It is only in the field that the gun carriage is placed upon the ground, in every other instance it has a platform of some description on which to stand and recoil. The platform is necessary with a heavy piece of ordnance, which remains in a fixed position for a considerable time, as the carriage would otherwise sink into the ground, when it would be difficult, if not impossible, to manœuvre the piece; the recoil would be too suddenly checked, causing the destruction of the carriage, and the firing would be inaccurate. The platform is made of wood, its length being regulated by the distance through which the gun recoils; the recoil is, however, checked to a certain extent by giving the platform a slight inclination to the rear (1 in 24), so that the gun, when loaded, may have to be run up through as small a space as possible. This inclination of the platform, if too great, would cause the piece to act injuriously upon both carriage and platform.

Madras plat-  
form.

The Madras platform, which is sometimes employed in the field, consists of two side pieces for the wheels of the carriage to run upon, and a trail piece for the trail; the side pieces are connected together by one front and two rear transoms, upon which they are bolted, and the trail piece is bolted to the two latter. The middle and rear parts of the side pieces are supported upon sleepers placed at right angles to them, and a third sleeper is placed under the rear of the trail piece. In traversing, the gun must be run up, and the handspikes applied to the ends of the side pieces (Fig. 2, Plate 17).

Clerk's plat-  
form.

A siege platform, proposed by Lieut. Col. Clerk, B.A., has



been lately introduced, which is of very simple construction, consisting merely of two side pieces, one trail piece, and two cross pieces or transoms; it can be packed for transport into a very small compass, and can be more readily laid and traversed than the Madras platform.

*Garrison Carriages, and Carriages for Coast Batteries.*

41. Garrison guns are mounted upon what are called, "Garrison Standing Carriages," but are not transported from place to place upon them, a separate class of carriages being required for the conveyance of both (garrison) gun and carriage.

42. The following principles must be observed in the construction of a garrison carriage :—

(1) The height of the carriage must depend upon the efficient working of the gun.<sup>1</sup>

(2) The carriage must be so constructed that it may be easily run up or back, traversed, or moved from one embrasure to another near to it.

(3) The carriage should occupy as little space as possible, for it may be exposed to enfilade or ricochet fire; and, moreover, it is desirable to have all the available space that can be obtained within the battery and under cover, for the conveyance of ordnance, stores, &c. from one part of the works to another.

(4) The material of which the carriage is composed must be capable of withstanding the exposure to the various changes of the atmosphere for a considerable period. A simple and strong elevating screw will also be required, as for other gun carriages.

Garrison  
standing  
carriage.

43. These carriages are generally made of wood, and are composed of two brackets, connected together by a transom, two bolts, and two axletrees; they are not mounted on wheels, but on four small iron trucks; elevation is given to the gun by means of quoin, and elevating screw. These carriages have no capsquares, as the guns mounted on them are very heavy, and consequently, have not such violent action when discharged, as lighter pieces. (Plate 12).

44. The howitzer carriages are of similar general construction to the gun carriages, but are strengthened with iron to a much greater extent, and have blocks of wood instead of the rear trucks.

Iron carriages. 45. In consequence of the rapid decay of wood in some climates, especially in the tropics, a certain number of carriages are made of iron with open brackets, but these have the following

<sup>1</sup> The height of the garrison carriage is such as to allow of the gun being fired over a 2 ft. 3 in. *genouillère* at a depression of 2°.

disadvantages, viz. that they weigh two-thirds heavier than the wooden ones,—that if struck by a shot they would be easily damaged, and the splinters from them would be very destructive.

Carriages for  
coast batteries.

46. For coast batteries, carriages of similar construction are employed, but they are usually mounted on traversing platforms, that they may be traversed with greater ease and rapidity, the objects upon which the guns of coast batteries are required to fire, being seldom stationary.

Traversing  
platforms.

47. Traversing platforms are of three kinds, viz. common dwarf, and casemate.

48. Common traversing platforms are employed to raise guns sufficiently high to enable them to fire over a parapet. They are made of either wood or iron; the latter material, used merely for the sake of durability and economy, is very objectionable, the platforms made of it being easily rendered unserviceable if struck by a shot; moreover, the splinters would be very destructive to the gun detachment, and the repair of the platform would be, generally speaking, impossible, at least with the ordinary means at disposal. The wooden platforms consist of two long side pieces placed upon four legs, having trucks, which run upon circular rollers let into the ground, and on the top of each side piece is a plank for the trucks of the carriage to run upon; there is also a ribband of wood inside each side piece to keep the trucks from running off. These platforms can be made to traverse either in front, centre, or rear, the central pivot being only employed when guns are mounted on circular towers; they have a slope of 1 in 12 to check the recoil, and facilitate the running up of the gun. The ordinary garrison carriage is used with this platform, the hind trucks being removed, and a block of wood substituted for them.

The advantages obtained by the use of these platforms are, (1) that the gun can traverse through a much greater angle than an embrasure will admit of: (2) that the parapet is much strengthened; and (3) that there is more cover for interior of the work. There are, however the following disadvantages, viz. (1) that guns mounted on them could be easily dismounted by ricochet or cross fire, in consequence of the large object they present above the parapet; (2) their great height above the ground renders the mounting guns upon them a comparatively difficult operation; (3) also the men working the guns are very much exposed.

49. Wooden dwarf traversing platforms have almost entirely superseded the common traversing platforms to which they are similar in general construction, and guns mounted upon them can fire through ordinary embrasures. By lengthening the

legs of a platform of this kind, the gun could fire over a parapet if required. The disadvantages attaching to the common traversing platform are thus obviated, and the gun can be more readily worked and mounted. The ordinary garrison carriage is used with them, but has blocks instead of axletrees, upon which it rests on the platform, the part of the block between the cheeks being deeper, and passing between them so as to keep the carriage in its place. In front of each bracket there is a pair of cheek-plates, in which works a gun-metal truck that comes into play when the rear of the carriage is hoisted up by the truck levers. This carriage is run up by means of tackle. (Fig. 1, Plate 17.)

These platforms were made to traverse on a pivot, but "raised racers"<sup>1</sup> are now substituted for the pivot, the platform resting on hollow soled trucks which run upon the racer (Fig. 1, Plate 17); the advantages of the latter arrangement are, that the strain of the recoil, which constantly caused the displacement or fracture of the pivot, is distributed over the length of racer; also that a smaller embrasure can be used with the racer, for its imaginary centre is nearer the muzzle of the gun than the pivot was, and the muzzle therefore moves but little laterally, when the gun is traversed.

50. There is also a low traversing platform, which is used for mounting guns in casemates; it has no legs in front, but traverses on a racer, let into the masonry. The gun carriage is similar to that for the dwarf traversing platform.

*Carriages for the Transport of Heavy Ordnance, their Carriages, &c.*

51. The carriages belonging to this class are the

Sling cart,  
Sling wagon,  
Platform wagon,  
Trench cart.

These carriages should be very strong, of simple construction, and great durability.

Sling cart.

52. The sling cart consists of an axletree and bed, over which a windlass is placed, and a pair of shafts; it is mounted on heavy wheels 6 ft. in diameter. It is employed for transporting guns and mortars through short distances, generally in garrisons, arsenals, &c. The manner of slinging guns, mortars, and their beds, is explained in the *Manual of Artillery Exercises*. The gun is slung with its muzzle to the front, the breech being lashed up to a small pry-hole projecting to the rear, which passes over the axletree, and under the transom, in front of the windlass.

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<sup>1</sup> Originally proposed by the late Col. Colquhoun, R.A. Adopted, see Circular, 13th March, 1860.

**Sling wagon.** 53. The sling wagon, instead of the shafts, has a perch (Plate 14), the eye of which hooks on to a straight pintail on the limber, thus forming a four-wheel carriage. The wheels are higher (7 ft.) than those of the sling cart, and the gun is slung with its muzzle to the rear, the breech being lashed up to the perch; besides the gun, its carriage (garrison standing) is also carried over the perch.

This is a most useful carriage for conveying large ordnance considerable distances, and, as the wheels are of large diameter, over very rough or uneven ground.

**Platform wagon.** 54. The platform wagon (Plate 15) is a wagon having no sides, and fitted up by means of wooden brackets, either for guns, mortars, or their beds; but generally speaking, for the two latter. This carriage is capable of carrying one 10-in. mortar and its bed, or two 8-in. mortars and their beds, or a gun and its carriage (placed over the gun).

**Trench cart.** 55. The trench cart is merely a small cart with shafts for single draught. 10-in. and 8-in. mortars and their beds, as also the small brass mortars, can be transported in trench carts, although they are used for a variety of other purposes.

#### *Naval Gun Carriages.*

56. Naval gun carriages may be classed as follows:—

For heavy guns,—

Common ship carriage,  
Rear-chock carriage,  
Sliding carriage,  
Jamming carriage.

For light pieces,—

Field carriages,  
Carriages for boat service.

**Ship carriage.** 57. The ordinary ship carriage is similar in construction to the garrison standing carriage, but is made of elm instead of oak, and has wooden trucks in the place of iron ones, which would act injuriously upon the deck of a vessel when the carriage recoils. On the rear axletree is placed a depressing block, which pivots at one end, and by means of it, 5 degrees of depression can be given to the gun; an additional small quoin is furnished to these carriages, which enables the gun to be still more depressed, provided the ports of the ship will admit of it. Blocks of wood are attached underneath the axletrees that the gun may be worked on them, if necessary, the trucks being removed.

These carriages are provided with capsquares, they are run up by means of tackle, and the recoil is limited by a breeching rope passing through the button of the gun, the ends of which are secured to staples let into the side of the vessel.

Rear-chock carriage.

58. The rear-chock carriage is similar to the above in construction, except that a block of wood is substituted for the rear axletree and trucks; it is run up by means of a roller handspike. (Plate 13).

Sliding carriages and naval slide.

59. The sliding carriage is also similar to the ship carriage in general construction, but has blocks both in front and rear, which rest upon a slide, called the "naval slide." There are two small trucks attached to the front of the brackets, similar to those of the carriage for the dwarf traversing platform, and two smaller trucks in rear, to each of which, a small iron lever is attached; when the gun requires running up, tackle is applied to each lever, which hoists the rear of the carriage on to the two small trucks, and at the same time brings the front trucks into play, the carriage will then run up without difficulty. The naval slide consists of two side pieces, connected together by a head block, and two under chocks (blocks of wood); there are two centre planks which allow of the application of a roller handspike for running up the gun, should the ordinary apparatus be out of order. The slide can be pivoted, either in front or rear, and the under chocks traverse on radius plates or racers let into the deck of the vessel. The carriages mounted on these slides have two iron compressors, one on each side, which, when screwed up, jam the rear block against the slide, and so check the recoil of the carriage on the slide.

These slides are intended for the pivot guns on board steamers.

Jamming carriage.

60. The jamming carriage, which is now almost obsolete, is somewhat similar in general construction to the ship carriage; it has no axletrees or trucks, the rear being supported by two legs projecting outside the slide upon which the carriage runs, there being a metal plate underneath the front of each bracket to work upon the slide; there are two iron plates screwed loosely to the inside of the brackets, one to each bracket, which can be made to grasp the slide, by tightening a long screw-bolt, passing through the plates and brackets, the recoil being thus checked.

Field carriages.

61. Field carriages for naval service are similar in general construction to those for land service; they differ in the following respects, viz.,—

The wheels are lower, 3 ft. 6 in. and 4 ft. 2 in.<sup>1</sup> instead of 5 ft.; the track is not so wide, 3 ft. 8 in. and 4 ft. 2 in.<sup>2</sup> instead of 5 ft.; and the trail is shorter, in order that it may make the angle 21° with the ground; this angle, as before stated, being

<sup>1</sup> 3 ft. 6 in. for 12-pr. howitzers.

4 ft. 2 in. for 24-pr. howitzers, and 6-pr. guns.

<sup>2</sup> 3 ft. 8 in. for 12-pr. howitzers.

4 ft. 2 in. for 24-pr. howitzers, and 6-pr. guns.

considered the best for the trails of field carriages. The limber has no splinter-bar, but is provided with a pair of shafts for single draught, and a pole; the limber boxes are placed so as to open from each side of the limber, instead of behind.

The pieces mounted on these carriages are—

6-pr. gun,  
12-pr. howitzer (light and heavy),  
24-pr. howitzer.

Carriages for  
boat service.

62. Guns for boat service are provided with two carriages, one of which is mounted on the top of the other. The top carriage for the 24-pr and 12-pr. howitzers, is similar to a ship carriage in general construction, and is mounted on a bottom carriage, consisting merely of a platform of wood having an axletree and two trucks in front, and two blocks of wood in rear. These two carriages when mounted one over the other, answer the purpose of an ordinary ship carriage, but when the gun is placed in a boat, the under carriage is removed, the upper one fitting on to a slide fixed inside the boat.

The top carriage for the 6-pr. consists of two brackets connected by two blocks, and is attached by a bolt to the under carriage, between the brackets of which it rests; considerable elevation can be given by this arrangement, which was intended to enable the gun to fire into the tops of the enemy's vessels.

#### *Mortar Beds.*

63. Mortars are not, like guns and howitzers, mounted upon carriages,<sup>1</sup> for being fired at very high angles of elevation, a carriage having wheels or trucks would not be capable of withstanding the shock of the discharge, the vertical strain from which is so very great. Beds of wood or iron of simple construction are therefore employed, the whole length of the bed resting on, and being supported by the platform. A mortar bed is provided with a quoin upon which the piece rests, usually at an angle of 45°, and also with bolts on each side, both in front and rear, for the convenience of running the mortar up or back (Plate 16).

64. In mortar vessels the mortar rests upon its wooden bed, which traverses on a central pivot over a large table of wood; this table is supported on circular pieces of India-rubber, about 2½ in. thick, which take the shock of the discharge of the mortar, and by their re-action prevent injury to the vessel.

65. The beds for

Sea service mortar	(13 and 10-in.)	are of wood.
Land do.	(13, 10, and 8-in.)	.. iron.
do.	(5½, and 4¾-in.)	.... wood.

<sup>1</sup> A travelling carriage for land service mortars has been proposed.

66. The distance to which mortars need being small, their platforms are much shorter than gun platforms, and have no slope, but are made horizontal.

Weight of Gun Carriages for Iron Guns and Howitzers.

Nature.	Rigs or Travelling.		Garrison with Tracks.		Carriages for Dwarf Traversing Platforms.
	Carriage.	Lumber.	Wooden Carriage.	Iron Carriage.	
	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.
66-pr. ....	—	—	—	—	15 0 25
54-pr. ....	—	—	—	—	16 2 22
32-pr. ....	23 3 5	—	15 1 2	23 2 0	13 1 25
24-pr. ....	23 3 5	7 1 27	13 2 23	21 2 0	—
15-pr. ....	15 1 23	—	13 3 1	15 3 15	—
8-in. gun	24 2 0	13 2 0	—	—	—
10-in. howitzer	23 3 5	—	—	—	13 1 0
6-in. howitzer	31 2 9	7 1 27	16 0 0	25 1 5	—
6-in. howitzer	24 1 13	—	14 0 0	15 1 15	—

\* Block Trail.

Weight of Traversing Platforms.

Nature of Platform.	Common Traversing Platform.		Dwarf Traversing Platform.	
	Wood.	Iron.	Wood.	Iron.
	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.
66-pr. ....	—	—	31 1 25	—
32-pr. ....	23 0 0	51 0 0	26 0 21	53 0 5
24-pr. ....	19 0 0	—	—	—
8-in. gun ...	25 1 3	—	26 0 21	53 0 5

Weight of Mortar Bed.

Nature of Bed.	Old Pattern.		New Pattern.	
	Wood.	Iron.	Wood.	Iron.
	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.	cwt. qrs. lbs.
13-in. S. S. *	—	—	57 2 13	—
10 " " "	—	—	33 1 13	—
13 " L. S.	—	35 2 23	—	35 2 20
10 " " "	—	16 1 16	—	17 3 16
8 " " "	—	7 2 27	—	8 3 3
5 1/2 " " "	1 0 10	—	—	—
4 1/2 " " "	0 3 5	—	—	—

\* The table on which the sea service 13-in. mortar bed rests on board ship, weighs 66 cwt. 3 qrs. The platform on which it rests, when used on land (fitted with India-rubber rings), weighs 50 cwt.

## AMMUNITION.

1. THE term "ammunition" is applied not only to the charges of powder for ordnance and small arms, but it also includes all kinds of projectiles used in the service, the various appliances for igniting the charges, &c.

2. The different kinds of ammunition may be classed as follows:—

Ammunition for ordnance.  
ditto small arms.  
Rockets.

### *Ammunition for Ordnance.*

3. In describing the ammunition for ordnance, and also that for small arms, the order followed will be,—(1) the projectile complete; (2) the charge; and (3) the means by which the charge is fired. Ammunition for ordnance will accordingly be divided into,

- (1) Projectiles, fuzes, sabôts.
- (2) Charges, cartridges, and wads.
- (3) Tubes, locks, portfires, &c.

Projectiles  
from ordnance.

4. The projectiles fired from ordnance in the service, are as follows:—

Shot	{	Round (solid and hollow).
		Grape.
		Common case or canister.
Shell	{	Common { Spherical.
		{ Elongated.
		Shrapnel.
		Armstrong's segment shell.
		Carcass.
		Light ball.
		Smoke ball.

Round shot.

5. Round shot are merely spheres of iron, cast either solid or hollow.

Solid shot.

6. Solid shot are fired from all guns in the service, except shell guns, but not from howitzers; they are most useful against troops in column, or in compact masses; also to destroy palisadings, buildings, &c., to dismount ordnance, and to breach revetments, for which purpose hollow shot or shells would be of little service; when made red-hot, they are very effective against shipping, or anything combustible. Solid shot may be used at all ranges.

7. The practice of double-shotting, that is, of firing two shot, or a shot and shell at the same time from the same gun, is sometimes resorted to by the navy, when ships are engaged at



short ranges;<sup>1</sup> reduced charges are used for this purpose, as with full charges the strain upon the metal of the gun would be greatly increased. Great irregularities occur in the paths described by the two shot, both in point of range and lateral divergence, arising, no doubt, from the decreased initial velocity, which renders greater elevation necessary, and also from the striking of the shot against each other within the bore. It has been found from experiment, that the two shot should be in actual contact, and not separated by a wad or sabôt, or the first will most probably be fractured by the impact of the other upon it. Double-shotting is not allowed with bored up guns, or with 8-in. guns of less than 60 cwt.

8. Sir H. Douglas states,—“It has been observed that, on running alongside of an enemy, the first broadside might be given with triple shot; and it is supposed that triple shot might answer the purpose, against flotillas of gun-boats at distances not exceeding 400 or 500 yards.” There would, however, be very great danger of the guns bursting, if fired with three shot at the same time.

**Eccentric shot.** 9. If the centre of gravity of a shot does not coincide with the geometrical centre of its figure, the shot is termed “eccentric.” Almost every shot that is cast is slightly eccentric, for, from the contraction of the metal on cooling, a cavity is formed in some part of the interior (rarely in the centre), and irregularities will be found in the exterior surface. The effect of this eccentricity upon the flight of the projectile will be explained hereafter, and it is only necessary to state here, that if the shot be placed in the bore with its centre of gravity above, and in the same vertical plane with, the centre of the figure, the range of the shot will be increased. In order to take advantage of this circumstance, the Prussians, and some other nations, have used shot made purposely eccentric, but such projectiles have been considered objectionable in our service; the increase in range thus obtained being variable, and therefore not to be depended on; great care being required in the loading; and should they happen to rotate on a vertical axis, the lateral deviations would be far greater than with ordinary shot.

10. Experiments were carried on at Shoeburyness and Portsmouth, in 1850, and again at the former place in 1851 and 1852, at the suggestion of Sir H. Douglas; the object of these experiments being, “To ascertain whether the deviations of eccentric projectiles were so regular as to admit of being allowed for in pointing the gun; and whether any result might appear to disprove the maxim, that spherical and homogeneous projectiles

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<sup>1</sup> Within 200 yards.

are the truest in their flight." The report of the Ordnance Select Committee on these experiments, stated, "That no useful application of the eccentric principle can be made in general service, and that its use is limited to cases, in which a more extended range may be required than is practicable under ordinary circumstances.

Tables shewing the results of the experiments carried on at Shoeburyness, are given in Boxer's Treatise, p. 167.

Hollow shot.

11. Hollow shot are fired from shell guns, and were introduced chiefly for the naval service, their advantages over solid shot being,—

- (1) Their large diameter, with comparatively small weight,
- (2) That they can be fired from lighter guns,
- (3) That they require a less charge of powder.

Their ranges and accuracy at considerable ranges are inferior to those of solid shot of equal diameter, for in consequence of the decreased weight of hollow shot they are more subject to retardation or deflection from the atmosphere. Hollow shot were special projectiles, but now they are merely empty common shells with metal screw plugs.

12. Commander Dahlgren in his work on *Shells, and Shell Guns*, objects altogether to the employment of hollow shot; asserting, that they should invariably be filled with powder, and used as common shells. He says, "It is, indeed, difficult to comprehend what possible purpose is to be effected by the adoption of hollow shot, if the cavity is not filled with powder, so as to obtain the advantage of explosion."

With respect to the effect of hollow shot upon ships, Sir H. Douglas states that, "Whilst, by their magnitude, fractures or apertures of great extent may be made in the side of an enemy's ship, their relatively lower momenta, arising from the diminished weight, render them far more conducive to the formation of destructive splinters than solid balls of equal diameters." It is, however, evident, that if loaded with powder, their destructive effect would be immensely increased.

Grape shot.

13. Tier grape shot, which has been substituted in the service for quilted grape, consists of a number of cast-iron balls, arranged in three tiers by means of three cast-iron circular plates, and a bottom plate of wrought-iron; the whole is secured firmly together by means of a wrought-iron pin, which passes through the centre of the plates. The number of shot in each tier varies from three to five, according to the nature of gun for which the grape shot is intended. (Fig. 1, Plate 18).

14. The quilted grape, formerly used, consisted of a number of iron balls placed in a canvas bag round an iron spindle, which

was attached to an iron tampion or bottom; the top of the bag was drawn tightly in underneath the top of the spindle, and the whole secured firmly together by means of the quilting line or cord. The number and weight of the balls differed, according to the nature of the grape shot.

15. The advantages of the tier over the quilted grape are, that it is more readily put together, more easily stowed, and is more durable,—the canvas and cord being liable to wear or become unserviceable from exposure. The effect produced by the tier grape is also generally considered to be greater than that of the quilted grape.

16. Grape shot is used for sea service, and for the attack and defence of works; it is exceedingly destructive if the range does not exceed 300 yds., and can be employed with considerable effect up to 600 yds., unless the ground be very uneven or much broken by obstacles, such as banks, hedges, &c. It is never fired from bronze guns as it injures their bores.

Common case  
shot, or  
canister.

17. Common case shot or canister (Fig. 2, Plate 18) consist of a number of cast-iron balls placed in a tin cylinder, having a wooden bottom, except the case for the 10-in. (sea service), the cylinder of which is of sheet iron, and has an iron top and bottom; the former having a handle for the convenience of loading. The balls vary in weight and diameter, and the number of balls differs, according to the nature of ordnance for which they are intended; for field service, the case contains 41 balls, which are placed in tiers. This kind of projectile is very effective at short ranges, from 1 to 300 yds. when the enemy's front is considerable, especially when the ground is hard and free from obstacles, and will be found most useful, when artillery is attacked in the field, or in the defence of works. Beyond 300 yds. the dispersion of the shot (the case being broken by the shock of the discharge) is too great to be effective.

Common shells.

18. Common shells are hollow spheres of cast-iron, having a circular hole cut through the metal for the insertion of a fuze, and are now filled with gunpowder; until lately the bursting charge only filled a certain portion of the interior of the shell, for it was considered that the smaller charge would cause the shell to break into larger fragments; it is, however, now thought that this is of less importance than the increased effect from the explosion of large charges of powder; besides which, the filled shell will probably be less eccentric than one partially loaded, and consequently, be more accurate in flight than the latter. The bursting charge is ignited at the required instant by means of a fuze.

The thickness of metal in a common shell must be such that,

the shell may contain as large a bursting charge as possible, but that it be strong enough to withstand the shock of the discharge within the bore of the gun. The thickness of metal in a common shell is about one sixth of its diameter, and the shell weighs about two-thirds of the weight of a solid shot of equal diameter.

Common (spherical) shells are of three kinds, viz.—

Mortar shells,  
Common shells (land service),  
Naval shells.

**Mortar shells.** 19. Mortar shells are fired without sabôts, and the larger natures 10 and 13-in. have two small “lugs,” or rings,<sup>1</sup> one on each side of the fuze hole, in order that they may be more easily lifted up by means of shell hooks, and adjusted correctly in the bore of the mortar (Fig. 3, Plate 18). The large mortar shells, 13, 10, and 8-in., are generally used in bombarding towns, and works, and for these purposes, it is desirable that the shell should penetrate and then burst, the fuze being therefore bored, as it is technically termed, “long” (Fig. 1, Plate 20); these shells are most useful in destroying, and setting fire to buildings and magazines, levelling earthworks, &c. The small mortar shells are generally fired against troops posted behind cover, and they should therefore be made to explode at the instant they reach the ground; if they penetrate into the ground, and then explode, the splinters will have little lateral range, and the destructive effect of the shells will be greatly decreased.<sup>2</sup> (Fig. 2, Plate 20).

**Common shells (land service).**

20. Common shells (land service) have no lugs, but are provided with sabôts, attached by means of a rivet to the bottom of the shell opposite the fuze hole (Fig. 3, Plate 19); these sabôts are necessary, in order that the fuze may be kept in the axis of the bore when loading, and no doubt, serve to decrease the rebounding of the shell within the bore, the gas acting more uniformly upon the sabôt than upon the surface of a shell without one. When carried loaded, a small gutta-percha wad is driven down the fuze hole to keep the powder dry and prevent its escape; this being further secured by a metal plug, which is screwed into the fuze hole, the latter being tapped with a female-screw. These shells are employed against troops in line or masses, especially when posted behind cover, also to destroy wooden buildings or earthworks; to set fire to combustible materials, &c.; when fired against troops (Fig. 3, Plate 20), the fuzes should be regulated so that the shells may explode immediately before reaching the ground, and among the troops;

<sup>1</sup> Lewis holes would supersede the lugs in future.

<sup>2</sup> The fuze holes of mortar shells issued loaded for naval service are secured with a bung and kit plaster.

against houses, earthworks, &c. the fuzes should be rather long. (Fig. 4, Plate 20).

**Naval shells.** 21. Naval shells are similar to common shells for land service, with the following exceptions, viz.—That they are always carried loaded with their fuzes, which are of metal, fixed, the fuze holes being bouched with gun-metal cylinders for the reception of the latter (Fig. 4, Plate 19).

Naval shells are chiefly employed against ships, and in order to produce the most destructive effect they should penetrate the side of a vessel, and then explode; in which case, they will cause the most frightful destruction between decks, and very probably, set the vessel on fire.

22. A number of experiments were carried on in France, to determine the effects produced by horizontal shell firing against shipping; these are described by Captain Simmons, R.A., in his work on *Heavy Ordnance*, p. 91—98.

Commander Dahlgren in his work on *Shells, and Shell Guns*, states that, “At Sinope their operation (of shells) was strikingly manifested, particularly as regards incendiary properties, which proved to be most formidable. One frigate was fired and blown up in five minutes from the shells of the ‘Constantine’s’ lower deck guns, and another shared a like fate, by the shells from the ‘Paris.’ The other ships were afterwards successively enveloped in flames, and the surviving Turkish officers, when questioned on the subject, at the instance of General Paixhans, concurred in attributing the conflagration to the shells.” Numerous instances of the destructive and incendiary effect of shells against shipping might be cited.

**Martin’s shells.** 23. A shell has been proposed (by a Mr Martin), as a substitute for red-hot shot, to be fired against shipping. The interior of the shell is coated with some non-conducting substance, to separate the molten iron, with which the shell is filled previous to firing, from the metal of the shell; it is intended that the shell on striking the side of the vessel should be broken by the impact of the molten iron upon the interior surface, and the heated metal being thus released produce conflagration; also, should it penetrate through the side of the vessel, it would, no doubt, inflict most terrible wounds upon the men between decks. A small cupola furnace would be required for heating the metal, and it is found that when the molten iron is poured into the shell it quickly sets at the plug-hole, no plug being therefore required.

**Common shells for Armstrong guns.** 24. Elongated common shells of cast-iron with a coating of lead will be used with the Armstrong rifled guns; shells of this

description fired in the experimental practice at Eastbourne in 1860, contained the following bursting charges :—

8 lbs. for 100-pr. shells.			
5½	”	80	”
2½	”	40	”

**Shrapnel shell.** 25. A shrapnel shell has a less thickness of metal than a common shell, viz. about one-tenth of its diameter, and its weight is about half of that of a solid shot of similar diameter. The bursting charge of a shrapnel shell should, if possible, merely open the shell and release the bullets with which it is filled. The shell is filled with bullets, and a small bursting charge; the latter is merely sufficient to open the shell at the required moment, being ignited by means of a fuze, and releases the bullets, which will then proceed onwards in nearly the same direction, and with the same velocity, that the shell had on bursting. The conditions to be fulfilled in a shrapnel shell are therefore,

(1) That the thickness of the metal should be such, that it will resist the explosion of the charge within the bore of the gun, but open readily with a small bursting charge.

(2) That the bursting charge should be merely sufficient to open the shell without affecting the flight of the bullets.

**Original Shrapnel shell.** 26. In the shells originally introduced by General Shrapnel, the bursting charge was poured loosely among the bullets inside the shell previous to fixing the fuze; experiments have shewn that by this arrangement, premature explosions frequently resulted (especially when full service charges are used) in consequence, as usually asserted, of the friction of the balls against each other, and the interior surface of the shell.

**Improved Shrapnel shell.** 27. The “improved” shrapnel shell was proposed by Captain Boxer, R.A., to obviate the defect of premature explosion; in this shell the bursting charge is entirely separated from the balls, by being placed in a metal cylinder extending from the fuze hole down the centre of the shell (Fig. 1, Plate 19), and the interstices between the balls are filled with melted rosin, to prevent the balls from being disfigured by the concussion of the discharge, or from breaking into the powder cylinder. In consequence of the complete separation of the bursting charge, a much smaller quantity of powder is required to burst the shell, and these shells can be fired with full service charges without danger of premature explosion, which is of great importance, the velocity and penetration of the bullets being thereby greatly increased. A modification of this shell is used by the Americans, and several Continental powers.

**Diaphragm shell.** 28. The “diaphragm” shell, invented by Capt. Boxer, R.A., has a wrought-iron partition or diaphragm, which separates the

bursting charge from the bullets (Fig. 2, Plate 19). The bursting charge in this shell is also much reduced, and the interior of the shell is coated with marine glue in order to insure complete separation between the powder of the bursting charge, and the coal dust with which the interstices between the bullets are filled up, instead of the rosin as in the improved shrapnel. The opening of the shell by the bursting charge is facilitated by four grooves formed in its interior surface, extending from the fuze hole to points near the bottom of the shell, forming so many lines of "least resistance." The balls or bullets placed in the interior of the shell are made of hard metal, viz. lead and antimony, in order that they may retain their correct form. The fuze hole, like that of the improved shrapnel is tapped with a female-screw, and fitted with a gun-metal socket, into which the fuze is placed; they are also furnished with gun-metal screw plugs.

29. Shrapnel shells are most effective against troops (especially cavalry) in line, column, or masses of any kind, when uncovered, and at considerable ranges. The effect produced by the bullets will chiefly depend upon the bursting of the shell at exactly the required instant; no precise rule can be absolutely laid down as to the distance short of the object at which the shell ought to burst, as so much will depend upon the velocity of the shell just before it opens, and other circumstances. It is generally considered that shrapnel shell should, if possible, be made to burst from 20 to 80 yds. short of the object; or in practice, the artillerist should endeavour to regulate the fuze, so that the shell may explode when about 50 yds. (the mean between 20 and 80) short of the object fired at. The bursting of a shrapnel shell at the proper distance from the object fired at, is of the very greatest importance; if the shell bursts too soon (the fuze being "short"), the whole or greater part of the balls will strike the ground before reaching the object, the velocity and penetrating power being greatly diminished in consequence; should the fuze be "long," that is, if the shell pass the object without exploding, the effect of the shell as a shrapnel will be entirely lost (Fig. 6, Plate 18).

Armstrong's  
segment shell.

30. The construction of the Armstrong segment shell has been varied from time to time, the results of experiments having suggested modifications. The following description has been given by Sir W. Armstrong.<sup>1</sup> "The projectile consists of a very thin cast-iron shell the interior of which is composed of forty-

<sup>1</sup> This extract and the following ones on Armstrong's fuses are taken from a paper on the Construction of Artillery, printed by the Institution of Civil Engineers, and permission has been kindly given to copy the drawings of shell and fuses in Plate 33.

two segment shaped pieces of cast-iron, built up in layers around a cylindrical cavity in the centre, which contains the bursting charge, and the concussion arrangement. The exterior of the shell is thinly coated with lead, which is applied by placing the shell in a mould, and pouring melted lead round it. The lead is allowed to percolate among the segments, so as to fill up the interstices, the central cavity being kept open by the insertion of a steel core. In this state the projectile is so compact that it might be fired through 6 ft. of hard timber without injury, while its resistance to a bursting force is so small, that less than one ounce of powder is sufficient to break it in pieces." (Fig. 6, Plate 32). It is capable of withstanding a very great force exerted on its exterior surface, on a similar principle to that followed in the construction of an arch. Using this projectile therefore as a shrapnel, the bursting charge will do little more than merely open the shell and liberate the different segments which will then move forward with the same velocity the shell had on bursting (Art. 25, Lect. VI). The projectile for the field gun can be used as shot, shrapnel, or case; for the first no fuze is used, for the second the fuze must be arranged for the required time of flight, and for the third so that the shell shall burst immediately after leaving the bore.<sup>1</sup>

Carcasses.

31. Carcasses are merely shells of greater thickness of metal than common shells of the same diameter, and having three vents instead of a fuze hole; the increase in the thickness of metal is necessary, in order that the shell may be capable of resisting the explosion of the charge with which it is fired, the three vents weakening the shell very considerably (Fig. 4, Plate 18). The interior of the shell is filled with a highly inflammatory composition, which being ignited by the discharge of the piece does not fracture the shell, but issues in a powerful flame from the vents for the space of eight or ten minutes, and upon the shell falling into a building, or among combustible material of any kind, the flames will produce conflagration; the nature of the composition is such, that it will burn under water and cannot be extinguished without the greatest difficulty. Carcasses are chiefly employed in bombarding towns, harbours, &c. and may be fired from mortars, howitzers, or guns, but generally speaking, from the former. Carcasses are fired with service charges, except the 18 and 10-in., which are fired with 16 and 9 lbs. respectively.

Light ball.

32. Light balls are of two kinds, viz.

The ground light,  
Boxer's suspended light.

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<sup>1</sup> The bursting charge for the 12-pr. shell is 9·6 dra., but it has been proposed to increase this to 11·5 dra.



The ground light ball (Fig. 5, Plate 18) consists of a cylindrical wrought-iron skeleton,  $1\frac{1}{4}$  calibres in length, with hemispherical ends; this skeleton is covered in canvas, the cylindrical part woolded with twine, and the former filled with a composition which, when ignited, burns for a considerable time (from five to fifteen minutes), with a red flame, there being four holes cut through the canvas to serve as vents for the flame. These lights are of four different natures, viz. 10, 8,  $5\frac{1}{4}$ , and  $4\frac{1}{2}$  in.; they are fired from mortars with reduced charges.

Light balls are generally employed by the garrison of a besieged place to discover at night the working parties of the enemy; they may also be thrown into the ditch to ascertain the strength and disposition of assaulting columns.

33. Boxer's suspended light may be briefly described as follows:—The exterior shell is a hollow sphere of paper cut in halves; in the bottom half is placed a hemisphere of tinned iron which holds the light composition, and has four vents on its exterior surface. A parachute of calico is packed into another iron hemisphere, which fits into the upper half of the paper shell; the parachute is connected to the hemisphere holding the light composition by a small strong chain. The halves of the paper shell are secured together by glue, and a linen band. A small bursting charge is inserted through a fuze hole at the top of the shell, and shaken between the paper and metal cases. The composition is the same as that used for signal lights. (See Art. 112 at the end of this Lecture). The projecting charge is placed in a flannel bag, and attached underneath the lower hemisphere; it is ignited by means of a piece of quickmatch passing round the exterior of the shell from the fuze. The shell is fired from a mortar at an elevation of about  $75^\circ$ , by means of a piece of quickmatch which projects from the muzzle, this being done to insure the ignition of the fuze; upon the bursting of the paper shell, the parachute is liberated and supported by the heated gas from the light, the flames of which issue from the vents in the lower hemisphere, the light continuing to float in the air descending gradually as the composition is consumed.

34. The suspended light was proposed by Captain Boxer; the ground light possessing the following defects, to which the former would not be subject:—(1) That the ground light can be smothered by shovelling earth over it; (2) that if the ground upon which it falls be soft, or should it lodge in a ditch or hollow, the light would be in a great measure obscured; (3) that if it be projected short of the object, the light would have a contrary effect to that intended; and (4) that its discovering power is very low, not exceeding 20 yards round the light. The

suspended light, from its elevation and great brilliancy, illuminates a very considerable extent of ground.

Smoke balls.

35. Smoke balls consist of a paper shell (the thickness of the paper depending upon the nature of the shell), which is filled with a composition that, upon ignition, evolves a large volume of smoke. These balls are employed for throwing into mines or other confined situations to suffocate or repel the working parties, &c.; also, to conceal your own position from an enemy.

36. The dimensions, &c. of the projectiles used with the smooth-bored ordnance of the service are given in the following Tables:—

*Dimensions, Weight, &c. of Shot, Shell, and Carcasses.*

Nature.		Mean.		Weight.						Remarks.	
		Dia- meter.	Thick- ness.	Empty.			Bur- sters.		Total Weight.		
		in.	in.	lb	oz	dr	lb	oz	dr		
Solid shot.	{ 68-pr.	7.925	...	...	...	...	...	...	...	Wood bottoms are attached to all shot for brass guns.	
	{ 56 "	7.48	...	...	...	...	...	...	...		
	{ 42 "	6.765	...	...	...	...	...	...	...		
	{ 32 "	6.177	...	...	...	...	...	...	...		
	{ 24 "	5.6115	...	...	...	...	...	...	...		
	{ 18 "	5.099	...	...	...	...	...	...	...		
	{ 12 "	4.5225	...	...	...	...	12	5	1		
	{ 9 "	4.1	...	...	...	...	9	4	7		
	{ 6 "	3.572	...	...	...	...	6	3	10		
{ 3 "	2.823	...	...	...	...	3	2	3			
{ Mortar	{ 13-in.	12.84	2.146	194	...	10	8	204	14	8	Mortar shells are not provided with wooden bottoms.
	{ 10 "	9.85	1.646	86	...	5	...	91	6	8	
	{ 8 "	7.86	1.39	46	...	2	4	48	10	...	
{ Common	{ 10-in.	9.85	1.646	86	...	5	0	92	9	15	{ Plugged with iron, & used as <i>hollow shot</i> , for land service.
	{ 8-in. or	7.86	1.39	46	...	2	4	49	9	13	
	{ 68-pr.	7.48	1.25	39	...	2	0	42	9	10	
	{ 56-pr.	6.765	1.132	28	...	1	6	30	15	2	
	{ 42 "	6.177	1.034	22	...	1	2	24	5	7	
	{ 24-pr. or	5.595	0.936	16	...	13	...	17	8	7	
	{ 5½-in.	5.099	0.803	12	...	10	...	13	2	5	
	{ 18-pr.	4.454	0.746	8	...	6	...	8	15	13	
	{ 12-pr. or	4.454	0.746	8	...	6	...	8	15	13	
	{ 4¼-in.	4.454	0.746	8	...	6	...	8	15	13	
{ Naval Boxer's and Moorsom's.	{ 10-in.	9.85	1.646	86	...	6	4	94	3	15	{ Naval shells are fitted with screw-metal plugs (which are readily removed), to enable them to be used either for <i>shell</i> or <i>hollow shot</i> .
	{ 8 "	7.86	1.39	46	...	2	4	49	14	13	
	{ 32-pr.	6.177	1.034	22	...	1	...	24	9	3	
{ Diaphm.	{ 8-in. or	7.95	1.026	36	12	...	60	60	12	...	338 bullets in each } 16 to } 1 lb. 110 } 77 } 20 52 } 29 } 1 lb.
	{ 68-pr.	6.177	0.786	17	8	...	40	29	3	6	
	{ 24 "	5.595	0.7116	12	13	...	30	21	2	12	
	{ 18 "	5.099	0.685	9	12	...	25	16	12	1	
	{ 12 "	4.454	0.567	6	2	...	20	10	8	4	
	{ 9 "	4.08	0.5167	4	9	...	15	7	14	1	
	{ 6 "	3.55	0.4556	3	6	...	10	5	8	8	
Carcasses	{ 13-in.	12.84	2.9	220	...	...	232	8	...		
	{ 10 "	9.84	2.11	96	...	...	102	4	...		
	{ 8 "	7.86	1.68	48	...	...	52	8	...		
	{ 24 "	5.595	1.2	15	...	...	16	1	...		
	{ 12-pr.	4.454	0.95	8	...	...	8	12	...		

NOTE.—The difference between the total weights of shells of the same calibre is owing to the different natures of wooden bottoms, metal screw plugs, &c., with which they are provided.

Dimensions, Weight, &c. of Case, Grape, and Light Balls.

Nature.	Mean.		Balls.		Weight.				Remarks.				
	Dia- meter.	Length.	No. in each.	Weight of each.	Empty.		Total Filled.						
Case...	Gun.	10-in.	9-82	7-6	{ 34 } 50	1	...	11 6	...	86 6 4			
		8 "	7-855	11-5	90	...	8	5 14	2 50	14 2			
		56-pr.	7-455	13-2	50	1	...	5 11	2 55	11 2			
		42 "	6-735	12-8	85	...	8	4 4	2 46	12 2			
		32 "	6-147	11-66	66	...	8	3 4	6 36	4 6			
		24 "	5-5795	10-92	46	...	8	2 7	2 26	7 2			
		18 "	5-074	10-11	46	...	6	2 0	10 19	4 10			
		12 "	4-464	9-4	41	...	6 1/2	1 2	8 17	13			
		9 "	4-0685	8-7	41	...	5	0 15	11 13	12 11			
		6 "	3-3405	7-66	41	...	3 1/2	0 11	2 9	0 6			
		3 "	2-808	6-2	41	...	1 1/2	0 6	10 4	4 2			
		Howitzer.	10-in.	9-82	13-78	170	...	8	9 7	...	94 7	...	
	8 "		7-82	9-02	258	...	2	5 12	8 38	0 8			
	32-pr.		6-147	6-45	105	...	3 1/2	1 11	8 23	0 12			
	24 "		5-57	5-64	100	...	2	1 9	8 14	1 8			
	Grape.	Howitzer.	12 "	4-432	5-05	50	...	2	1	...	12 7	4 12	
			Gun.	10-in.	9-82	8-16	24	3	...	11 6	...	83 6	...
				68-pr.	7-82	9-38	15	3	...	21 8	...	68	...
56 "				7-45	10-26	12	4	...	20	...	56 8	...	
42 "		6-735		9-76	9	4	...	12 8	...	48 8	...		
32 "		6-147		8-78	9	3	...	9 4	...	36 4	...		
24 "		5-57		7-68	9	2	...	6	...	26	...		
18 "		5-074		6-86	9	1	8	6	...	19 8	...		
12 "		4-432		6-18	9	1	...	4	...	13	...		
9 "		4-06		5-78	9	...	13 1/2	3 7	...	10 7 2			
6 "		3-532		4-76	9	...	8	2	...	6 8	...		
Light Balls		10-in.		9-375	14-1	...	...	...	31 8	...	63 10 8		
		8 "		7-6	11-25	...	...	...	16 8	...	32 15	...	
		5 1/2 "		5-4	7-625	...	...	...	1 12	...	10 9 8		
		4 1/2 "		4-125	6-25	...	...	...	1 4	...	5 2	...	

Fuzes.

37. Fuzes are used with shells, the object for which they are employed being to ignite the bursting charge at the required moment. There are a great many varieties of fuzes in the different European services, but those at present in our service are,

Wooden fuzes :—

- Boxer's common shell fuze,
- shrapnel ditto.
- mortar ditto.
- Freeburn's concussion ditto.

Metal fuzes :—

- Boxer's naval time fuze,
- Moorsom's percussion fuze,
- Armstrong's time fuze,
- percussion fuze.

38. Boxer's fuzes (including his naval fuzes), are what are termed "time" fuzes, and they consist of a case of wood or metal, conical in form, into which is pressed the fuze composition; this composition burns progressively and regularly, at the rate of 1 in. in five seconds, so that any length may be given to it, to correspond with the time of flight of the shell, by boring a small hole through the case into this composition, thus making a communication for the flame into the bursting charge within

the shell. These fuzes, and also the concussion fuze, are ignited by the flame from the discharge of the piece, which envelopes the shell, the top of the fuze composition being primed to render its ignition effectual. The percussion fuzes are not ignited in the above manner, but by the impact of the shell against the object, there being an arrangement inside the fuze by which this is effected.

39. The conditions to be fulfilled in time fuzes are :—

- (1) That they should ignite with certainty,
- (2) That they should burn regularly,
- (3) That when ignited, they should not be liable to extinction on striking earth, water, or wood.<sup>1</sup>

Boxer's  
common shell,  
and Shrapnel  
fuzes.

40. Boxer's common shell and shrapnel fuzes are of similar construction, except that the former is longer, and contains 2 in. of composition, the shrapnel fuze containing but 1 in. of composition. In these fuzes (Fig. 1, Plate 21) the composition bore is made eccentric with regard to the exterior, and there are two powder channels bored parallel to the composition on that side in which there is the greatest thickness of wood. Side holes, .2 in. apart,<sup>2</sup> are made into the powder channels, those into one powder channel indicating the even, and those into the other channel the odd tenths of fuze composition; the bottom hole of each row is continued into the axis of the composition bore, in order to insure the eventual bursting of the shell, should the boring of the required hole previous to firing not have been properly executed. A hole is bored through the priming and to a depth of .4 in. into the composition, in order to insure the ignition of the fuze, a greater surface of the composition being thus exposed to the flame from the priming.

In order to prepare the fuze for any given range, an augur is inserted into the side hole marked with the number of tenths corresponding to the time of flight, and the bit is forced into the composition; a communication is thus made for the flame into the powder channel, and the fine powder with which the latter is filled, conducts it instantaneously into the shell. These fuzes have a metallic cap to preserve the priming, inside of which is a disk of card-board, having a piece of tape attached to it; when the shell is inserted into the bore of the piece, the cap is readily removed by pulling the tape upwards.

Mortar fuze.

41. In the mortar fuze (Fig. 5, Plate 21) the axis of the composition bore is identical with that of the fuze, and there are no powder channels; the latter are not required, as any hole at which the fuze may be bored will always fall within the interior

<sup>1</sup> This is rarely fulfilled.

<sup>2</sup> The top hole of one row is .2 in., and the top hole of the other .3 in. below the bottom of the priming hole.

of the shell, the times of flight being greater for mortar shells than for shells fired at low angles, and consequently the lengths of fuze composition. These fuzes, the composition in which is 6 in. long, have one set of side-holes which are placed spirally round the fuze, in order to prevent the wood from splitting when it is being bored. A hole is bored into the top of the composition, and another through the lowest side hole, as in the common shell and shrapnel fuzes, and the fuze is also provided with a cap.

Naval fuzes.

42. Naval fuzes are made of metal, either brass or bronze, and are screwed into the fuze holes of the shells; they are stronger and more serviceable than wooden fuzes, and are not so easily knocked out on striking any hard substance, such as the side of a vessel (Fig. 2, Plate 21). The chief objections to the use of metal, instead of wood, for the cases of fuzes are,—That the metal has an injurious effect upon the fuze composition, unless entirely separated from it; and also, that metal is a more expensive material, requiring a greater amount of time and labour to work it into the required form.<sup>1</sup>

43. These fuzes are of two natures, viz.

The long range fuze, which burns for 20 seconds,  
 „ short „ „ 7½ „

The composition of the long range fuze is 4 in. in length, and the short range fuze 3 in.; the former is ordinary fuze composition, and the latter meal powder; the 20 seconds fuze can only be employed when the time of flight of the shell is 7½ seconds, or upwards, the first side-hole being bored 1½ in. from the top of the composition. They are both provided with two sets of side-holes, but have no powder channels; the composition is separated from the metal by a thin cylinder of rolled paper, which is introduced into the fuze before driving the composition. The required length of fuze composition is given by forcing an augur at the proper side-hole through the clay with which it is filled, and the cylinder of paper. These fuzes have metal caps which screw on to them, that for the short range having a red ring upon it to distinguish it from the 20 seconds fuze.

Percussion and concussion fuzes.

44. Percussion and concussion fuzes are intended principally for naval service, the action of the fuze depending upon the striking of the shell against a substance that offers a very considerable resistance, such as the side of a ship.

45. The essential requirements of a good percussion fuze, are,—

(1) That it shall not be ignited by the shock of the discharge;

<sup>1</sup> Metal fuzes can however be easily cast so as to require but little turning and finishing; they are in very general use on the Continent.

(2) That it may resist impact against any material upon which it may ricochet.<sup>1</sup>

(3) That when the shell strikes the object, the force of the impact may produce the desired action. The two latter apply also to the concussion fuze.

Freeburn's  
concussion  
fuze.

46. Freeburn's concussion fuze (Fig. 3, Plate 21), is simply an ordinary wooden case with a composition bore down the centre, which is rather more than half-filled with fuze composition; three small wedges of gun-metal are fitted into the wood round the upper part of the composition, the larger end of the wedges being towards the composition. When the shell is fired, the wedges being supported by the composition are not displaced by the shock of the discharge; but on the shell striking the object at a considerable range, the composition will have been consumed to some distance below the wedges, thus leaving them unsupported, and they will therefore fall into the composition bore, the flame at the same time making its way through the empty spaces into the shell.

Moorsom's  
fuze.

47. Moorsom's percussion fuze is made of metal (brass or bronze), and screwed into the shell (naval) like the ordinary naval fuze. It has within it three cylindrical chambers, in each of which is a hammer of brass suspended on a copper wire, and one or two caps, containing detonating composition. The two upper chambers are arranged in a similar manner, and cross each other at right angles. In (Fig. 4, Plate 21) *AB* and *A'B'* are the upper chambers, *a* and *a'* the hammers suspended on the wires *b* and *b'*; *c* and *c'* are the caps which can only be seen in the upper chamber. A small channel is perforated through each cap to serve as a communication for the gas from the priming into the interior of the shell. In the lower chamber *A''B''*, *a''* is the hammer, *b''* the wires (there are two for this hammer), and *c''* the cap, which communicates with the channel *d*, having a small magazine at each end.

The action of the fuze is as follows:—

The copper wires are broken by the shock of the discharge of the gun, and the hammers are then released, and allowed to slide in the chambers; when the shell strikes any hard substance, one or more of the hammers will come violently in contact with their respective caps, and explode the shell. The reason for having three chambers is to insure the ignition of the fuze, whatever part of the shell strikes the object.

Armstrong  
fuzes.

48. As there is no windage with this gun, and consequently no escape of gas round the projectile, the ordinary time-fuze would not ignite, there is therefore in Sir W. Armstrong's time-

<sup>1</sup> This has special reference to the fuze of a shell fired at a vessel, and which might ricochet on water before striking the object.

fuze a percussion arrangement by means of which the composition is ignited by the shock of the discharge; the general principle of this fuze is similar to that of Briethaupt. (See Art. 51), but there is in addition the percussion arrangement.

Time fuze.

Sir W. Armstrong has thus described his fuzes. "The body of the time-fuze (Fig. 7, Pl. 30) is made of a mixture of lead and tin, cast to the required form in a mould. The fuze composition (meal powder) is stamped into a channel forming nearly an entire circle round the body of the fuze, and is afterwards papered and varnished on the external surfaces. As the shell fits accurately into the gun, there was no passage of flame, by which the fuze could be ignited. The effect is therefore produced in the following manner :—A small quantity of detonating composition is deposited at the bottom of the cylindrical cavity in the centre of the fuze, and above this was placed a small weight or striker terminating in a sharp point presented downwards. This striker is secured in its place by a pin, which when the gun is fired is broken by reason of the *vis inertiae* of the striker. The detonator is then instantly pierced by the point and is thus fired. The flame thus produced passes into an annular space, formed within the revolving cover, which rests on the upper surface of the fuze composition, and from this annular space it is directed outwards through an opening so as to impinge on and to ignite the fuze composition at any required part of the circle. The fuze thus ignited burns in both directions, but only takes effect at one extremity, when it communicates with a small magazine of powder in the centre. The fuze is surrounded by a scale paper, graduated to accord with the elevation of the gun, so that when the range of a distant object is found by trial, it is only necessary to turn the igniting aperture of the cover to the point on the fuze-scale corresponding with the degrees and minutes of elevation on the tangent scale."

Concussion fuze.

49. "The concussion fuze (Fig. 8, Plate 30) is on nearly the same principle. A striker with a point presented upwards is secured in a tube by a wire fastening, which is broken on the firing of the gun; the striker being thus liberated recedes through a small space, and rests at the bottom of the tube, but as soon as the shell meets with any check in its motion, the striker runs forward and pierces the detonator in front, by which means the bursting charge is ignited."

Foreign fuzes.

50. Of the fuzes used by Continental Powers, those most worthy of notice are the Bormann fuze, invented by Captain Bormann of the Belgian Service, and a fuze proposed by Captain Breithaupt of the Austrian army, which is an improvement on the former.

Bormann fuze.

The Bormann fuze consists of a small metal disc, about  $1\frac{1}{2}$  in.

in diameter, and  $\frac{1}{8}$  in. thick, made of lead hardened with tin, and cast in a mould. The composition is condensed into a channel (*aa*, Figs. 2 and 3, Plate 22), which passes round the upper portion of the disc parallel to its exterior surface, and has a thin covering of soft metal pressed down over it, but which will yield readily to the cutting tool. The covering is graduated into seconds,  $\frac{1}{2}$ , and  $\frac{1}{4}$  seconds, and the end of the composition over which the numeration begins, communicates with a small magazine (*b*, Figs. 2 and 3, Plate 22) at the centre of the disc charged with fine powder, but slightly closed at the bottom, so as to yield in that direction to the explosion. The fuze is made with a thread round it so that it may be screwed into the shell, and in order to support it at the moment of the discharge, it is made to rest upon a metal plate (*cc*, Fig. 3, Plate 22) screwed into the shell before the fuze, the plate being perforated to allow the flame to pass through it into the shell.

The action of this fuze is as follows:—The thin metal covering above the composition is cut at the desired graduation, according to the time of flight, so as to afford the flame from the discharge access to the composition; the latter being ignited burns round to the commencement of the graduation, from which it passes into the magazine, explodes it, and also the charge inside the shell. The composition at the ending of the graduation has no communication with the central magazine.

This fuze possesses several very important advantages:—(1) the whole composition being compressed at once instead of in separate layers, its combustion will be more regular than that pressed in the ordinary way; (2) the composition is securely protected from moisture, and not liable to explode prematurely; (3) the fuze does not project from the shell, and its preparation or cutting can be performed after it is screwed into the shell, so that the latter can be issued or transported in the field with the fuze ready fixed.

Breithaupt  
fuze.

51. The Breithaupt fuze is similar in principle to the Bormann fuze, but has in addition a regulating disc, by means of which it can be adjusted to any required time of flight without any boring or cutting. This fuze is made of a mixture of tin and lead, and the composition arranged and pressed in like that of the Bormann fuze, the communication with the magazine being however rather different. The regulating disc (*aa*, Figs. 4, 5, and 6, Plate 22) is made of the same material as the fuze, and it has a small priming chamber (*b*, Figs. 4, 5, and 6, Plate 22), a red line upon which serves as an index; by turning the disc round, this chamber can be brought over any required portion of the composition. The priming chamber is prepared with a small strand of quickmatch bent double, and covered



with a paste of meal powder, a cap of gold-beater's skin serving to preserve the priming from moisture. A screw (*c*, Figs. 4 and 6, Plate 22) passes through the disc, which when home keeps the latter firmly in its place. The disc has a bottom covering of leather in order that it may be in close contact with the fuze, and preserve the composition from moisture. The graduated circle extends beyond the disc, and is divided into eighths of a second (Fig. 4, Plate 22).

The fuzes hitherto made are only for field service; for shrapnel shells the fuze composition is meal powder, which burns for seven seconds; for common shells, it is ordinary fuze composition, which burns for fourteen seconds. The advantage this fuze possesses over the Bormann fuze is that no cutting is required, for the disc being turned until the priming rests over the desired part of the composition, then secured by tightening the screw, the fuze is ready for firing by merely tearing off the cap over the priming chamber.

#### Sabôts.

52. Shells for guns and howitzers, and all projectiles for field pieces are provided with wooden bottoms or sabôts which, until lately, were attached to the projectiles by means of tin strapping. The following is the manner in which sabôts are fixed to shot and shell:<sup>1</sup>—A small hole in the form of the frustrum of a cone is drilled to the depth of one-tenth of an inch into the shell opposite the fuze-hole, the base of the cone inwards; a gun-metal rivet, which passes through the centre of the sabôt is placed in this conical hole, and with a few blows of a hammer, the top of the rivet, which is hollow, expands into the interior of the hole, and is thus retained in the shell. The rivet has a small head to prevent the sabôt from slipping off it, but this head is bevelled off, in order that it may not hold on any portion of the sabôt after the projectile has received the blow from the discharge of the piece. The sabôts (Plate 19), which are of elm,<sup>2</sup> are turned down to the low gauge of the shot or shell for which they are intended.

In order when firing shot and shell together that the two should be in actual contact, for the reason given in Art. 7, the sabôt of the naval shell is cut completely through round the centre (Fig. 4, Plate 19), and there are two rivets by which it is attached to the shell.

#### Charges.

53. For land service, there are certain fixed charges, termed service charges, for all guns and howitzers. The amount of powder in the service charge of a gun should be such, that it will give the greatest initial velocity, to the projectile, without

<sup>1</sup> Introduced by Captain Boxer, R.A.

<sup>2</sup> Teak is substituted for elm in sabôts for tropical climates.

too great strain upon the metal of the piece, or a too violent recoil of the gun, which latter, would act very injuriously upon the carriage; the greater the initial velocity the less will be the angle of elevation required for any given range, and consequently, the more accurate the practice.

54. For heavy and medium guns, the service charge is about  $\frac{1}{3}$ , and for light guns about  $\frac{1}{4}$ th the weight of the shot. The service charge is now used for 32-pr., and all natures below that gun, whether firing shot, shell, or shrapnel. For the 8 and 10-in. guns, shot and shell are fired with the service charge, but with the 8-in. improved shrapnel,<sup>1</sup> a reduction of 2 lbs. is made. A reduction is also made in the charges of the 68 and 56-pr. guns, in firing common shell or improved shrapnel.<sup>2</sup> Very reduced charges are used for saluting purposes. (See Table, Lecture III).

The charge for hot shot ought not to exceed  $\frac{2}{3}$  the service charge, for in consequence of the expansion of the shot and the adjacent metal of the bore the windage is reduced, and a greater strain will be exerted upon the metal of the gun; the expansion of the gas will also very probably be increased by the heat generated within the bore; moreover, very great penetration is not required, the object to be attained is, that the shot shall merely lodge in the timber.

55. The service charges for howitzers, which have already been given in the Table, Lecture III., are

For iron howitzers  $\frac{1}{2}$  weight of shell.

.. brass .....  $\frac{1}{4}$  to  $\frac{1}{3}$  .....

In ricochet firing these charges are greatly reduced, from one-twentieth to one-thirtieth the weight of shell being generally used; but no fixed charges can be laid down for this purpose, alterations having constantly to be made in them according to circumstances.

56. In the navy, three charges are used, viz. distant, full, and reduced. With respect to the advantages derived from the employment of reduced charges, Sir H. Douglas has the following remarks:—"In close action, shot discharged from large guns with the full quantity of powder, tear off fewer splinters than balls fired from the same nature of guns with reduced charges. This may be familiarly exemplified by firing a musket or a pistol charged with a bullet through panes of glass, at different distances, or with different charges. Superior velocity will make a clean round hole, without breaking or even cracking the plate; but a certain reduced celerity will dash the glass to pieces.

<sup>1</sup> This is the general rule; there are exceptions, as for instance, the 9-pr. gun, the service charge for which is only 2 lb. 8 oz.

<sup>2</sup> This does not apply to diaphragm shell, which is intended to be fired with the charge used for shot.

"In firing into masses of timber, or any solid substance, that velocity which can but just penetrate will occasion the greatest shake, and tear off the greatest number, and largest splinters; for, as in the brittle glass, the part struck by a solid shot, moving with great velocity, are driven out before they communicate motion to the circumjacent parts of the substance."

57. The charges for rifled ordnance are much less than those of smooth-bored pieces carrying projectiles of equal weight. Instead of being  $\frac{1}{3}$  or  $\frac{1}{4}$  the weight of the projectile, the charge for an Armstrong rifled gun is generally, only  $\frac{1}{8}$ ; it must however be remembered that this small charge will have a much greater proportional effect, for the Armstrong gun has no windage, and there is therefore no escape of gas; also, great force being required to compress the lead coating of the projectile into the grooved portion of the bore, time is most probably allowed for the conversion of the whole charge into gas before motion is communicated to the projectile.

**Cartridges.** 58. In our service, the charges for cannon and howitzers, after being accurately weighed out, are placed in cartridges made of serge, and secured with worsted; serge is used in preference to paper or parchment, (1) because it resists the action of travelling better; (2) as it is not liable to leave sparks in the gun.

**Fixed ammunition.** 59. When the cartridge is attached to the projectile, the two together are termed, "fixed ammunition;" this is only employed in our service with the 3-pr. mountain service ammunition.

With fixed ammunition, simultaneous loading is more simple, and the cartridge is sure to be placed correctly in the bore and not with the choked end first, as is sometimes the case when the projectile and cartridge are separate. Fixed ammunition has however the following disadvantage, viz. that in packing or stowing, much greater space is required, and it is more difficult to arrange. The French use fixed ammunition for field service.

**Powder cases.** 60. Cartridges are packed in wooden boxes lined with tinned copper; these are closed with a circular metal bung, which is luted all round to exclude the air, and a square lid of wood which screws firmly down, and can be opened by means of a metal key for the purpose.

These boxes are of three sizes, viz.

Whole, containing about 110 lbs.

Half ditto 55 "

Quarter ditto 28 "

The amount of powder which the box contains depends to a certain extent upon the size of the cartridge.

61. In steamers, where the space is limited, metal cases are used (called Dell's cases) in the form of a six-sided prism.

These cases are also of three sizes, viz.

Whole,	containing about	110 lbs.
Half	ditto	55 „
Quarter	ditto	28 „

62. Spare powder is made up into cartridges of 15 lbs. each, 8 of which can be put into either of the above "whole" cases.

63. Powder for mortars is placed in what are called "budge barrels," which are made of wood, and provided with a covering of leather.

Wads.

64. Wads are of two kinds, viz. "junk" and "grummet" wads.<sup>1</sup> The former are made of oakum, bound round with spun yarn, and are of similar diameter to the bore of the gun for which they are intended; their thickness, which depends upon the nature of the wad, varies from one to several inches. They are used in firing hot shot, and occasionally with bronze pieces to prevent indentation of the bore near the seat of the shot; in both cases they are placed between the charge and projectile. They are also used in proving ordnance, one or more being placed in front of the projectile.

65. The grummet wad consists of a circle of rope, equal in diameter to the bore of the gun, and having two cross-pieces of rope tied to the circle, and crossing each other at right angles. These wads are generally rammed in after the shot, in order to prevent its rolling forwards should the bore be depressed, or if it is shaken by the running-up of the gun; they are seldom used if the elevation exceeds 2°.

66. If no wads are at hand, the shot might be kept from rolling forwards by what is called a wad-stick, which is merely a long stick passing down the bore, and jammed tightly between the ball and the bore.

Different ways  
of firing ord-  
nance.

67. The charge in the bore of a piece of ordnance may be ignited in various ways; that in general use in our service is by means of the friction tube, which is altogether the most simple and effective. Other tubes are also employed which require locks, portfires, &c. to ignite them; and if no tube of any kind is at hand, the gun may be fired by pouring loose powder into the vent, and using a portfire or slowmatch. Should the vent be closed or stopped up, if the gun is spiked for instance, the charge may be fired by a piece of quickmatch placed down the bore, and ignited at the muzzle.

Action of a  
tube.

68. "The peculiar action of a tube, viz. that of igniting gunpowder or a similar composition, when placed at some

<sup>1</sup> A greased wad is used with the Armstrong guns in order to lubricate the bore.

distance from it, is due to the motion given to the heated gas by its own elastic force. The velocity with which the gas will issue from the tube will depend principally upon the amount of pressure which the particles have been subjected to in the cavity; now, this pressure increases in proportion to the quantity of gas generated, and diminishes as the space which is occupied by the gas increases. If this principle be taken into account, it is evident that a small cavity in a tube is more advantageous than a large one; for the quantities of gas are as the ignited surfaces, whereas the spaces occupied by the gas are as the squares of these surfaces; therefore, by increasing the cavity the quantity of gas is increased, and the amount of its elasticity will be at the same time diminished."<sup>1</sup>

**Different kinds of tubes.** 69. There are six different kinds of tubes in the service, viz.

- (1) Common or quill tube.
- (2) Dutch or paper tube.
- (3) Common metal tube.
- (4) Detonating quill tube.
- (5) Metal, and quill friction tube.
- (6) Galvanic tube.

The barrels of these tubes are gauged to two-tenths of an inch, and filled with meal powder dampened with spirits of wine, a hollow being made through this composition in each, to insure the correct action of the tube.

The first three tubes are fired by means of a portfire, the fourth by a lock, the fifth by a lanyard, and the sixth by means of copper wires leading from the galvanic battery.

**Common quill tube.** 70. The common quill tube (Fig. 1, Plate 23) consists of a quill barrel, the large end being cut into prongs which are turned back, and a cup formed upon them by twisting worsted over and under each prong in succession. Meal powder, dampened in spirits of wine is rubbed into the cup, which is then filled with dry meal powder and capped with paper; the cap which is not tied but only twisted underneath the cup, is removed previous to firing.

**Dutch or paper tube.** 71. The barrel and cup of the Dutch or paper tube (Fig. 2, Plate 23) are both made of paper; the priming of the latter, consisting of meal powder dampened in spirits of wine is worked into the form of a cone, and afterwards dipped in dry meal powder. The cap is of paper dipped in a solution of saltpetre, and secured underneath the cup with twine; this cup is not removed on firing. These tubes can be readily made on a deficiency of others.

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<sup>1</sup> Captain Buss's Manuscript Notes.

Common or  
metal tube.

72. These tubes (Fig. 3, Plate 23) are generally made of copper or brass; the cup is soldered on to the barrel, and has four holes pierced through it from the outside to give a rough surface for the priming to adhere to. They are filled, primed, and capped in a similar manner to common quill tubes.

Detonating  
quill tube.

73. The barrel of this tube (Fig. 4, Plate 23) is made of quill, and has a small cross-piece or tube placed at right angles to the barrel through a hole near one end; the cross-piece is secured to the barrel by means of silk, and contains the detonating composition. The tube is ignited by the fall of the hammer of the percussion lock upon the cross-piece.

Metal and  
quill friction  
tubes.

74. The metal friction tube (Fig. 5, Plate 23) is made entirely of copper. A short piece of tubing is fixed near one end of the barrel, and at right angles to it, a hole of communication being bored through the barrel into the tubing. A small piece of copper, having its surface roughened, is placed in the centre of the small tubing, the outer end being formed into a ring, to which the lanyard is hooked. A small pat of detonating composition is placed above and below this strip, and the small tubing is compressed on to it by means of a pair of pincers. The strip on being pulled smartly from the tubing, causes sufficient friction to ignite the detonating composition.

75. The quill friction tube (Fig. 6, Plate 23) is made on the same principle as the above, only quill is used instead of copper, the latter being objectionable for the naval service from the injury it might occasion to men between decks. This tube has a small loop of leather attached to it, opposite to the strip; the loop passes over an iron pin on the surface of the gun, and prevents the tube from being bent or withdrawn from the vent when the lanyard is pulled.

These tubes are fired by means of a lanyard, which is merely a piece of cord, having a metal hook at one end to fit into the ring of the tube.

Galvanic tube.

76. The barrels of these tubes (Fig. 7, Plate 23) are of quill; the cup which is of wood, is fixed on to the large end of the quill, and has two pieces of copper tubing passing through it, connected together inside the cup by a small platinum or steel wire, over which the priming is placed. When the tube is placed in the vent of the gun to be fired, the ends of the two wires from the battery are inserted into the copper tubes, one in each; upon the circuit of electricity being completed, the small wire within the cup becomes red-hot, in consequence of the resistance which it offers to the passage of the electricity from one wire to the other, and thus ignites the priming. These tubes are used for the "proof" of ordnance.

**Lock.** 77. In the lock now in the service, the hammer which is made of wrought-iron is pivoted in a long slot, so that after the tube is fired, it is drawn back by the continued action of the lanyard, and uncovers the vent; it would otherwise be thrown back with great violence, and very probably cause injury to the lock. The socket in which the hammer is fixed is made of gun-metal, and fitted to the right side of the gun for sea service, and to the left for land service. The locks are secured by iron pins which pass through the vent plate.

**Portfires.** 78. The portfires used for artillery purposes are of two kinds, viz. common portfires, and slow portfires.

79. The common portfire consists of a paper case about 16 inches long, into which is driven a composition which burns at the rate of one inch in a minute.

80. The slow portfire consists merely of paper impregnated with saltpetre, and rolled into a solid cylinder about 16 inches long, which will burn from three to four hours. These are readily made on a deficiency of other portfires.

**Match.** 81. There are two kinds of match, viz. cotton quick match, and slow match. The former is merely cotton, coated with a composition of powder, gum, and water, and is used for a variety of purposes, as for instance in firing trains of powder; also, under certain circumstances, ordnance, rockets, &c.

82. Slow match consists merely of hempen rope loosely twisted, and dipped in a solution of saltpetre and lime-water. It is very useful in firing charges of powder, when it is necessary that some time should elapse between the ignition of the match and that of the powder; it burns at the rate of one yard in three hours.

#### *Ammunition for Small Arms.*

83. This ammunition may be divided into,

- (1) Bullets,
- (2) Cartridges,
- (3) Caps.

**Bullets.** 84. Bullets in the service are of two kinds—spherical and elongated. The former are now merely used for shrapnel shells, and no longer as projectiles for small arms; they are cast in the ordinary way. The elongated bullet for the service rifle is cylindro-conoidal in form, and is now made by compression, a process described in the manuscript notes on the manufacture of bullets. There is a conical hollow in the base of the bullet into

which a small box-wood plug fits. The principle of this bullet will be explained in the Lecture on Rifled Small Arms and Ordnance.

85. In every bullet that is cast, there is a small cavity in the interior, and also a number of irregularities on the surface of the bullet, as before explained; by compressing the metal, uniform density, and smoothness of surface are secured.

Cartridges. 86. Cartridges for the ordinary service rifle are of two kinds, viz.

Ball cartridge.  
Blank do.

Ball cartridges. 87. The powder for the ball cartridge is placed in a cylinder of thick paper, round which is rolled a thin paper cover, the latter forming a bottom to the cylinder to prevent the powder from falling through upon the bullet; the top of the thin paper, which projects considerably above the thick paper, is closed after the powder has been inserted, simply by twisting it round, and it can readily be torn off when required. A third paper is wrapped round the bullet choked underneath it, and into the part projecting above the bullet the powder cylinder is placed, the paper bottom of the latter having been previously pressed inwards, so that it may fit over the top of the bullet. The paper containing the ball is secured to the powder cylinder by a small paper band, which is gummed (to cause it to adhere), and wrapped round the two. Several slits are cut in the paper which surrounds the bullet; these prevent the adhesion of the paper to the bullet after it has left the bore, which would cause great irregularities in flight. The part of the cartridge round the cylindrical portion of the bullet is lubricated with wax, in order to prevent the fouling of the bore from continued firing, the residue of the charge left within it on explosion, adhering to the wax.

88. In loading with this cartridge, the twisted end of the paper is torn off, the powder poured into the barrel, and the lower end of the cartridge placed in, so that the point of the bullet is uppermost; the paper projecting above the barrel is then torn off, merely leaving the band of paper coated with wax round the cylindrical part of the bullet, and the latter is then rammed down.

Blank cartridges. 89. In order that there may be but one uniform system of loading in the service, a blank cartridge has been introduced by Captain Boxer, R.A., which, having a paper bullet instead of the leaden one, can be loaded in precisely the same manner as the ball cartridge; any mistake that might arise in practice, from the soldier being taught two different ways of loading, being thus prevented.



90. In this cartridge there are only two paper cases; the inner one for the powder is very thick, and the other into the bottom of which the paper bullet is placed is much thinner; a circular piece is cut out of the bottom of the latter case and covered with lawn, so that when the charge is ignited, the flame penetrates into the bullet, and explodes the powder with which it is filled, this being necessary in order to avoid accidents from the projection of the bullet. The cases are made from pulp, by a process, which will be explained in the notes on the manufacture of cartridges.<sup>1</sup> The blank cartridges are lubricated in a similar manner to the ball cartridges, from which they are distinguished by a band of purple paper wrapped round them (the blank). Cartridges are made up into bundles of ten each, wrapped in cartridge paper, and packed in small barrels of oak,—ball cartridges in quarter barrels, and blank in half barrels.

*Percussion cap.* 91. A percussion cap is a small cylinder of copper, one end of which is closed, and contains a quantity of detonating composition; the cap is placed on the nipple of the lock of a musket, and ignited by the sudden blow from the hammer, the nipple being hollow in order to afford a passage for the flame into the bottom of the barrel where the charge is placed. The service cap is made of thicker metal than the ordinary sporting cap, and has a rim round the bottom, so as to give the man using it a firmer hold. Caps for land service are placed in small paper cones which contains 15 each; they are then packed in six cylinders in proportion to the number of cartridges packed in the barrel. 15 caps to every 10 ball cartridges, and 66 caps to every 60 rounds of blank; the cylinders are stowed in the centre of the cartridge barrels. Caps for naval service are packed in jars, glazed within and without, and secured at the top with a covering of India-rubber, each jar contains 1000 caps.

#### *Rockets.*

*General description and principle of the rocket.*

92. A rocket consists of a cylindrical case of paper or metal, containing an inflammable composition; to one end of the case is attached a head usually of a conical or cylindro-conoidal form, and the other end is closed, but has one or more vents or holes in it for the escape of the gas from the ignited composition. The composition is driven into the case over a conical spindle, passing to a certain distance up the centre, thus leaving a hollow space in the interior of the rocket, the base of the hollow cone coinciding with that of the rocket.

93. The object of having this cavity in the interior of the rocket is,—that a large surface of composition may be at once

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<sup>1</sup> The notes referred to are written by the Cadets of the Royal Military Academy.

ignited when the rocket is fired, and a great quantity of gas generated within the case which cannot escape from the vent so quickly as formed, and therefore exerts a pressure in every direction on the interior surface of the rocket. The pressures on the sides of the rocket mutually balance each other, but the pressure on the head is greater than that on the base in consequence of the escape of gas from the vent or vents; it is this excess of pressure on the head over that on the base, which causes the rocket to move forwards, this being merely a similar action to the recoil of a gun fired without a projectile.

94. The force which produces motion in a rocket is therefore different from that which acts upon a projectile fired from a piece of ordnance; the former is a "constant" force producing accelerated motion in the rocket until the resistance of the air is equal to the force, or the composition is consumed, while the latter may be considered merely as an "impulsive" force, which ceases to act upon the projectile when it has left the bore of the piece. The nature of the force which acts upon the rocket is more fully explained in Boxer's Chapter on Rockets, p. 67.

95. A stick or long rod is attached to the base or side of the rocket in order to counteract, by the resistance of the air upon it, any tendency to rotation, and to maintain the rocket during its flight as nearly as possible in the direction in which it is fired;—the stick should be strictly in prolongation of the axis of the rocket. The use of the stick, and the principles which should regulate its position and form, are explained at length in Boxer's Chapter on Rockets, p. 74.

96. There are two descriptions of rockets used in the service, viz.

The signal rocket  
„ congrève do.

The former, as its name implies, is employed for making signals, and the latter as a destructive projectile.

97. Signal rockets in the service are of two natures, viz. 1 lb. and  $\frac{1}{2}$  lb. The case and head are made of strong paper, the former containing the rocket composition, and the latter the composition for the stars; the bottom of the case is choked in so as to form a single vent in the axis, and the stick is in the rocket attached to the side, a very defective arrangement, for reasons given by Captain Boxer, p. 76 of Chapter on Rockets. These rockets are fired vertically or nearly so; when the composition is consumed, the bursting charge explodes the head and ignites the stars, which in falling produce a brilliant light, that can be seen to a great distance.

98. According to Robins, rockets between 1 and 2 in. in diameter, ascend vertically to a height of from 450 to 600 yards;

those whose diameters are from 2 to 3 in. to a height of from 1000 to 1200 yards. He also ascertained from experiment, that they could be seen within a circuit of from 35 to 40 miles, their time of ascent being 7 to 10 seconds.

Congreve  
rockets.

99. Although rockets had been used for war purposes (it is generally supposed) for centuries in the East, and at an early date even in Europe,<sup>1</sup> they were of little practical utility, until improvements in their construction and manufacture were introduced by Sir William Congreve, at the beginning of the present century. Five natures of rockets were proposed by that officer, viz. 3, 6, 12, 24, and 32-prs.; the latter are, however, no longer in the service.

100. The case for the Congreve rocket (Fig. 1, Plate 24) is made of sheet-iron, and the composition with which it is driven is stronger than the ordinary rocket composition. The composition is protected from the injurious action of the metal of the case, by paper lining which is painted, as well as the interior of the case. A hollow iron head, cylindro-conoidal in form, is screwed on to one end of the case, which can be filled with powder when intended to act as a shell, but left empty if only intended for a shot. The larger natures of rockets (24 and 12-prs.) can be used as carcasses by substituting for the ordinary head a conical one with four vents, and filled with carcass composition (Fig. 3, Plate 24).

101. Every rocket is fitted with a fuze fixed in the base of the shell, and there is a small hole in the apex of the shell for the insertion of the bursting charge, and through which the boring bit is introduced when it is required to bore into the fuze composition; this hole is closed by a metal screw plug, which can easily be removed, in order to insert the bursting powder. When the rocket is required to act as a shell at very long ranges, the fuze composition is not bored into, but as the range is reduced a greater quantity of fuze composition is bored out; and at the shortest ranges, the whole of the fuze composition, and also a portion of the rocket composition is bored through, to within  $1\frac{1}{2}$  in. of the top of the hollow cone in the 24-pr. rocket, and to within 1 inch in the other natures.

102. It is considered by many officers, that the time required for boring the fuze, and the danger of the operation is not compensated by the increased effect produced by the bursting of the shell.

103. The bottom of the case is closed by an iron disk having a centre hole into which the stick is screwed, and five other holes

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<sup>1</sup> See note, p. 65, of chapter on Rockets, by Boxer.

or vents (for the escape of the gas) equidistant from each other and from the centre hole (Fig. 4, Plate 24). The stick being thus placed in the axis of the rocket is a great improvement on the old way of attaching it to the side.

104. Congreve rockets are fired from iron tubes raised sufficiently above the ground (to keep the stick off it) by means of legs, and having a suitable arrangement for giving the required elevation; they may also be fired by laying them upon the ground, the head of the rocket being slightly elevated; a number of the smaller natures placed in a row, and fired in this manner would, no doubt, prove very effective against troops, particularly cavalry. Congreve rockets are employed, both in the land and naval services, for bombarding towns, in order to set fire to the houses, shipping, &c.

105. The advantages of rockets over other projectiles are thus stated by Sir W. Congreve:—"The rocket carcass is not only fired without re-action upon the point from which it is discharged, but is also unencumbered with the necessity of heavy ordnance to protect it, as is the case with every other carcass. It is, ammunition without ordnance,—it is the soul of artillery without the body; and has, therefore, from the first principles of its flight, a decided advantage for the conveniency of use, over the spherical carcass."

106. It is, however, impossible with the rockets and tubes now in use to obtain anything like accuracy of fire, and rockets can therefore be used only against objects covering a considerable extent of ground. A wind blowing across the range will cause great deflections with rockets, for the centre of gravity of the rocket and stick being so far forward, the wind acting upon the great length of the latter, will turn the rocket up into the wind; in order to allow for a side-wind, it must always be remembered that the rocket should be laid to leeward of the object, this being the reverse of what would be done in pointing a piece of ordnance.

Hale's rockets,

107. A rocket has been proposed by Mr Hale, which can be used without a stick. The case is similar to that of a Congreve rocket, except the base, which is in the form of a frustrum of a cone, having a large vent hole through its axis, and five small holes cut through its exterior surface into the rocket in an oblique direction, termed "tangential holes." The object of these holes is to give the rocket, by the escape of the gas through them, a rotatory motion on its longer axis, in consequence of which it will proceed forwards in its flight point foremost, as in the case of an elongated projectile fired from a rifled cannon; the stick can therefore be dispensed with, and the body of the

flame allowed to escape through the large vent in the centre of the base.

108. In firing these rockets, they were not allowed to leave the tube until they had acquired sufficient velocity to overcome the pressure of a small spring; they were thus prevented from "drooping," to which they would be liable if allowed to leave the tube with a very low velocity. A rotatory motion was also imparted by the tube, which was made of iron hoops twisted into a spiral form.

109. The principal objection to these rockets is, that the composition being quickly consumed, the rocket will then lose the rotatory motion, and therefore not continue point foremost, but will strike an object in an accidental position, and without any flame issuing from it, which is one of the most valuable properties of the rocket.

*Compositions.*

Carcasses. 110. The composition with which carcasses are filled is composed of

	lbs.	oz.
Saltpetre .....	6	4
Sulphur .....	2	8
Rosin .....	1	14
Sulphide of antimony <sup>1</sup> ...	0	10
Tallow .....	0	10
Venice turpentine.....	0	10

Ground light. 111. The composition for the ground light is

	lbs.	oz.
Ground saltpetre .....	6	4
Sulphur .....	2	8
Powdered rosin.....	1	14
Linseed oil (boiled) .....	0	7½

Signal light. 112. Signal light composition is composed of

	lbs.	oz.
Saltpetre .....	7	0
Sulphur .....	1	12
Sulphide of arsenic <sup>2</sup> .....	0	8

Smoke balls, 113. For filling smoke balls, the composition is

	lbs.	oz.
Dust powder .....	5	0
Saltpetre .....	1	0
Pounded coal .....	1	8
Swedish pitch .....	2	0
Tallow .....	0	8

114. The following dry composition is also used in filling the case :—

	Sulphur.	Pounded coal.
	oz.	oz.
For 13-in. smoke ball ...	2	2
10-in. „ ...	1	1
8-in. „ ...	½	½

<sup>1</sup> Sulphide of antimony, called in commerce, crude antimony.

<sup>2</sup> Sulphide of arsenic, realgar, or orpiment.

Fuses.

115. Fuze composition is composed of

	lbs.	oz.
Saltpetre .....	3	4
Sulphur .....	1	0
Mealed powder.....	2	12

Tubes.

116. The barrels of all tubes are filled with meal powder damped with spirits of wine.

117. The composition for igniting detonating and friction tubes.

Tubes.	Chlorate of Potash.	Antimony Crude.	Cylinder Mealed Powder.	Sulphur Sublimed.	Glass Ground.	
Detonating quill tube	48	48	4	4	13	} Parts.
Friction do do	12	12	1	1	0	
do do copper do	12	12	0	1	0	

Portfires.

118. The composition with which common portfires are driven is

	lbs.	oz.
Saltpetre .....	1	8
Sublimed sulphur.....	0	8
Dust powder .....	1	4

119. The solution with which the paper for slow portfires is impregnated consists of

Saltpetre .....	12 ozs.
Water .....	1 gallon.

Quickmatch.

120. The ingredients for making the several descriptions of quickmatch, are given in the following Table :—

	Four thread Match.	Six thread Match.	Ten thread Match.
Cotton ...	1 lb. 10 oz.	2 lbs. 2 oz.	2 lbs. 7 oz.
Water .....	8 pints.	9 pints.	10 pints.
Gum .....	8 oz.	9 oz.	10 oz.
Powder ...	20 lbs.	22 lbs.	24 lbs.

Copper caps.

121. The detonating composition for percussion caps is composed of

	Parts.
Fulminating mercury ..	2
Chlorate of potash ....	3
Ground glass .....	1

Rockets.

122. The composition for signal rockets consists of

	lbs.	oz.
Saltpetre .....	4	0
Sublimed sulphur.....	1	0
Dogwood charcoal ....	1	8

123. The ingredients for the star composition are,

Sublimed sulphur.....	2 lbs.
Saltpetre .... ..	8 lbs.
Sulphide of antimony ..	2 lbs.
Mealed powder.....	1 lb.
Vinegar .....	1 quart.
Spirits of wine.....	1 pint.
Isinglass .....	3½ oz.

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## GUNNERY.

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### *General Principles.*

1. A PROJECTILE when discharged from a piece of ordnance is acted upon by three forces, viz.

- (1) The force of projection from the charge of gunpowder ;
- (2) The force of gravity ;
- (3) The resistance of the atmosphere.

Let us examine briefly the effect of each of these forces upon a shot fired horizontally from a gun, the axis of which is represented by  $AB$  (Fig. 1, Plate 25).

2. If the projectile were acted upon by the force of projection alone, which ceases immediately it has left the bore, it would, by the first law of motion, proceed onwards in the direction  $AC$  with an uniform velocity, and would, in consequence, pass over equal spaces in equal times ; let us suppose it to pass over the distance  $BC$  in one second of time. Should the shot be only subject to the action of gravity, for instance, if it be allowed merely to drop from  $B$ , it would descend in the vertical direction  $BD$ , and would drop through a distance  $BD$  equal to about 16 ft. in one second. Since, however, the projectile is acted upon by both of these forces, if the two motions be compounded, and the parallelogram  $BDEC$  constructed, it will, by the second law of motion, have arrived at the point  $E$  in one second. Also, because gravity is an accelerating force, and the spaces through which a body under its influence will fall in successive seconds are as the squares of the times, the trajectory or path of the shot will pass through the points  $EFG$ , and thus describe a parabolic curve as shewn in the figure. The properties of this curve being known, the trajectory, time of flight, &c. of any projectile could be readily calculated if in its flight the shot was merely subject to the two above-named forces.<sup>1</sup> With low velocities of 200 or 300 ft. per second, the parabolic theory gives tolerably accurate results, and the following formulæ may therefore be found useful in certain cases of practical gunnery :—

Let  $V$  = initial velocity,

$R$  = range,

$T$  = time of flight,

$a$  = angle of projection,

$x$  and  $y$  = horizontal and vertical co-ordinates.

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<sup>1</sup> For Parabolic Theory, see Boxer's Treatise, Chapter IV.



The equation for the trajectory is,—

$$y = x \tan a - \frac{gx^2}{2V^2 \cos^2 a}, \dots\dots\dots (1)$$

$$R = \frac{V^2 \sin 2a}{g}, \dots\dots\dots (2)$$

$$T = \frac{1}{V} \sqrt{R \tan a}. \dots\dots\dots (3)$$

3. We must now consider the third force, viz. the resistance of the atmosphere which so modifies the curve as to render the parabolic theory inapplicable for the purposes of calculation with a high velocity. To projectiles moving with high velocities, there is a very considerable resistance from the atmosphere, which is generally said to vary as the square of the velocity, although Robins considered that when the velocity exceeded 1100 or 1200 ft. a second, the resistance would instantly be nearly trebled; these ideas are, however, incorrect (see Boxer, Art. 234, page 106). From Dr Hutton's experiments it appears that the resistance increases gradually up to about 1500 ft. per second (with the 2-in. ball), when its ratio to the velocity is as the 2·153 power of the latter, but that when the velocity exceeds this, the ratio again diminishes, for at the velocity of 1600 ft., it is as the 2·152 power, and so on till at the velocity of 2000 ft. it is only as the 2·136 power (see Table, page 102, Boxer). However, in certain cases for the sake of simplicity, the resistance of the atmosphere may be assumed to vary as the square of the velocity; as for instance, in comparing the effect of the resistance of the air upon projectiles of different diameters, densities, &c.

4. Dr Hutton in his thirty-seventh Tract, thus explains the nature of this resistance :—

“The circumstance of the variable and increasing exponent in the ratio of the resistance, is owing chiefly to the increasing degree of vacuity left behind the ball, in its flight through the air, and to the condensation of the air before it. It is well known that air can only rush into a vacuum with a certain degree of velocity, viz. about 1200 or 1400 ft. in a second of time; therefore, as the ball moves through the air, there is always left behind a kind of vacuum, either partial or complete; that as the velocity is greater, the degree of vacuity behind goes on increasing, till at length, when the ball moves as rapidly as the air can rush in and follow it, the vacuum behind the ball is complete, and so continues complete ever after, as the ball continues to move with all greater degrees of velocity. Now the resistance, which the ball suffers in its flight, is of a triple nature; one part of it being in consequence of the ‘vis inertia’ of the particles of air, which the ball strikes in its course; another part from the accumulation of the elastic air before the ball; and the

third part arises from the continued pressure of the air on the fore part of the ball, when the velocity of this is such as to leave a vacuum behind it in its flight, either wholly or in part; for, while the ball is at rest, it is manifest that this pressure of the whole atmosphere is the same or equal on all sides of the ball; but, as soon as the ball begins to move, it is also manifest that the pressure behind will be less than the constant degree of pressure in front, and the difference must be the greater as the motion of the ball is the more rapid, being, in fact, proportional nearly as the velocity of the ball as compared with that of air rushing into a complete vacuum, that is, while the former is not greater than the latter; for, as soon as the motion of the ball becomes equal to that of the air, and always when greater, then the ball has to sustain the whole pressure of the atmosphere on its fore part, without having any aid from a counter-pressure behind.

"Thus then we see that the resistance against the ball is twofold (besides that arising from the unknown degree of compression before the ball), the one arising from percussion, by the ball striking and displacing the particles of air in its path, and which increases continually in the duplicate proportion of the ball's velocity; and the other from the weight of the atmosphere, increasing with that velocity, to which, being of the nature of pressure, it is proportional; but arriving at its maximum when that is equal to or exceeds the velocity of air into a vacuum, after which it is a constant quantity for all greater degrees of velocity. These circumstances then very well shew the reason why the experimental resistance proceeds in a ratio increasing gradually more and more above the square of the velocity, till this exceeds twelve or fourteen hundred feet, the motion of air into a vacuum, and then rather decreases again. So that it appears that the whole estimatable resistance consists of two parts; of which the one part is proportional to the square of the velocity, and the other is simply as the velocity only."

Hutton's formula in two terms for this resistance is

$$mv^2 + nv = r,$$

$m$  and  $n$  being general coefficients determined by experiment.

In later experiments, different powers of the velocity have been introduced. In General Didion's formula, the first term is proportional to the square, and the second term to the cube of the velocity. M. de St. Robert, of the Sardinian artillery, has in his formula made the first term proportional to the square, and the second term to the fourth power, and this formula has been applied with some alteration in the coefficients, by Col. Mayefski of the Russian artillery, who carried on experiments in Russia in 1858.

*Definitions.*

5. Before proceeding it is considered advisable to give a few definitions in order to avoid confusion of terms.

**Range.** The "range" of a projectile is the distance of the first graze from the muzzle of the gun; it depends, as will be seen, upon the initial velocity, the form of projectile, the angle of elevation of the gun, and the difference of level between the gun and object.

**Deflection.** The "deflection" of a projectile is the perpendicular distance of the first graze from the line passing through the sights of the gun and the object; the causes of deflection will be explained at length in Lecture VIII.

**Initial velocity.** The velocity with which a projectile leaves the bore of the gun from which it is fired is termed its "initial velocity."

**Final or remaining velocity.** The "final" or "remaining velocity" of a projectile, is its velocity at the end of any given range.

**Terminal velocity.** If a body be allowed to fall in the atmosphere, there is a certain limit to the velocity it will acquire, and this is attained theoretically when the resistance of the air has become equal to the accelerating force of gravity; the motion of the body will then be uniform, and is called its "terminal velocity."

*Initial Velocity.*

**Dr Hutton's formulæ for initial velocity.** 6. Before correct ideas can be formed on the most important practical questions in gunnery, it is necessary to determine the initial velocities of projectiles; the ballistic and gun pendulums have been generally employed for this purpose, and a full description of them is given in Boxer's Treatise, Chap. II.

The following formulæ were deduced by Dr Hutton from an extensive series of experiments, carried on by himself at Woolwich with the aid of the ballistic pendulum.

**Initial velocities of balls of equal weights, when fired from same gun with different charges.** 7. The velocities generated by the action of different charges of powder in the same gun upon balls of equal densities, are nearly as the square roots of these charges; or

$$v : v' :: \sqrt{c} : \sqrt{c'}.$$

**When the weights of the balls are different, but the charges equal.** 8. The velocities generated by the same charge of powder from the same gun upon balls of different densities, will be inversely as the square roots of the weights; or

$$v : v' :: \sqrt{w'} : \sqrt{w}.$$

**When the charges are different, and also the weights of the balls.** 9. The velocities generated by different charges of powder upon balls of different densities, will be nearly in the ratio of the square roots of the charges, divided by the square roots of the weights of the balls (Boxer, pp. 50, 51); or

$$v : v' :: \sqrt{\frac{c}{w}} : \sqrt{\frac{c'}{w'}}.$$

In the above

- $v$  and  $v'$  are the initial velocities,
- $c$  = charge with  $v$ ,
- $c'$  = do  $v'$ ,
- $w$  = weight of ball with  $v$ ,
- $w'$  = do do  $v'$ .

Formula for initial velocity. 10. The empirical formula generally used in our service for ascertaining the initial velocity of a projectile, is as follows :—

$$V = 1600 \sqrt{\frac{ac}{w}},$$

- when  $V$  = initial velocity,
- $a$  = a coefficient, the value of which depends upon windage,
- $c$  = the charge (in lbs.),
- $w$  = the weight of ball (in lbs.)

The values of  $a$  found by experiment are,

	$a$
for windage of .233 .....	3.2
..... .2 .....	3.4
..... .175 .....	3.6
..... .125 .....	4.4
..... .09 .....	5.

Should there be no windage,  $a$  would equal 6.66.

To find the initial velocity of a mortar shell. 11. This formula should strictly be used only for the velocities of projectiles fired from smooth-bored ordnance of 17 to 19 calibres in length, and it could not therefore be applied to ascertain the velocities of mortar shells, the bore of a mortar being always so very short ; these latter velocities could however be determined in the following manner :—

If a 13-in. mortar shell be fired with a charge of 1 lb. 12 oz., it will range about 400 yards, and its trajectory may, for this short range, be assumed to be a parabola.

From formula (2) Art. 2, the angle of elevation being  $45^\circ$ ,

$$R = \frac{V^2}{g},$$

$$V^2 = 1200 \times 32,$$

$$V = 196 \text{ ft.}$$

The initial velocity of this shell fired with another charge of powder can be found from the ratio in Art. 7.

12. Dr Hutton draws also the following conclusions (in his thirty-seventh Tract) from his experiments :—

Effect of  
charge on  
velocity.

(1) “ It appears that the velocity (initial) of a ball increases with the increase of charge only to a certain point, which is peculiar to each gun, when it is greatest ; and that, by further increasing the charge, the velocity gradually diminishes till the bore is quite full of powder. That this charge for the greatest velocity is greater as the gun is longer, but yet not greater in so high a proportion as the length of the gun is ; so that the part of the bore filled with powder bears a less proportion to the whole bore in the long guns, than it does in the shorter ones ; the part which is filled being, indeed, nearly in the inverse ratio of the square root of the empty part.

Effect of length  
of gun on ini-  
tial velocity.

(2) “ It appears that the velocity (initial) with equal charges, always increases as the gun is longer ; though the increase in velocity is but very small in comparison to the increase in length, the velocities being in a ratio somewhat less than that of the square roots of the length of the bore, but greater than that of the cube roots of the same, and is, indeed, nearly in the middle ratio between the two.

Time of flight  
as the range.

(3) “ It appears, from the Table of Ranges, that the range increases in a much lower ratio than the velocity, the gun and elevation being the same ; and when this is compared with the proportion of the velocity and length of gun, in the last paragraph, it is evident that we gain extremely little in the range by a great increase in the length of the gun, with the same charge of powder. In fact, the range is nearly as the fifth root of the length of the bore, which is so small an increase, as to amount only to about one-seventh part more range for a double length of gun. From the same Table, it also appears, that the time of the ball’s flight is nearly as the range, the gun and elevation being the same.

No effect on  
velocity by  
varying the  
weight of gun,  
&c.

(4) “ It has been found by these experiments, that no difference is caused in the velocity or range by varying the weight of the gun, nor by the use of wads, nor by the different degrees of ramming, nor by firing the charge of powder in different parts of it ; but that a very great difference in the velocity arises from a small difference in windage.”

Effect of  
windage.

Advantages of  
employing  
electricity for  
determining  
the initial  
velocities of  
projectiles.

13. Many attempts have during the last few years been made to employ electricity as a means for determining the velocities of projectiles, and the most complete apparatus, hitherto invented for this purpose, is that of Major Navez, of the Belgian service.<sup>1</sup>

<sup>1</sup> The idea of determining the velocities of projectiles by means of electricity was first suggested many years ago by Professor Wheatstone, who invented an instrument called the electro-magnetic-chronoscope for this purpose.

The advantages derived by the employment of an electro-ballistic apparatus are as follows:—The velocities of a projectile at different points of the trajectory can be obtained by the same experiment; or, if a piece be fired at a high angle of elevation, the initial velocity of its projectile can be ascertained; for either of these purposes the ballistic pendulum would be useless. The electro-ballistic apparatus occupies but little space, it is inexpensive, can be easily removed, will serve for guns of all calibres, and can be operated with much greater celerity than the ballistic pendulum, the core of which requires to be constantly changed.

Naves' electro-ballistic apparatus.

14. The following is a description<sup>1</sup> of the construction and operation of the electro-ballistic apparatus:—

The pendulum.

The pendulum (Fig. 5, Plate 26), has two electro-magnets,<sup>2</sup> a straight magnet (*a*), and a horse-shoe magnet (*bb*); the former is adjusted so that, when magnetized by a current of electricity, it will just sustain the bob (*c*) of the pendulum, into which a small piece of soft iron is inserted. When the pendulum is released, it vibrates along the graduated arc (*dd*), carrying with it an index needle having a vernier at the end (*e*), and this index needle is fixed to a soft iron washer (*f*) through which the axis of the pendulum passes. The horse-shoe magnet, if made active by an electric current, attracts the washer and so clamps the index needle. The arc is graduated from 0° to 150°, and the vernier of the index needle contains a space of 9 half-degrees, divided into 10 parts, so that by its use  $\frac{1}{10}$ th of  $\frac{1}{2}$ °, or  $\frac{1}{20}$ th of 1° can be read. Four pressure screws (*w*) act upon connecting wires and establish the necessary communications, so that the currents may pass through the magnets.

The conjunctor.

15. A straight electro-magnet (*a*) is supported between two brass rods (*bb*), which are furnished with pressure screws (*cc*), for the purpose of securing the conducting wires; when the circuit is completed the current passing through the rods and magnet, magnetizes the latter; the plate, which supports the magnet, is insulated by ivory rings, to prevent the current passing on it from one rod to the other. Under the magnet is an iron cup with a little mercury in it, and a copper band (*e*) puts the cup in communication with the pressure screw (*f*); to the pressure screw (*g*) a steel blade (*h*) is attached, the opposite extremity of which is placed immediately over the orifice of the iron cup, and it has a small pin underneath pointing to the

<sup>1</sup> The details for this description have been taken from a pamphlet by Major Navez, translated by Lieut.-Colonel Younghusband, R.A.

<sup>2</sup> Soft iron magnets, which are made "active" by the intervention of an electric current, take the name of "electro-magnets" or "temporary magnets," in order to distinguish them from tempered steel magnets, which, retaining their magnetism for an indefinite period, are called "permanent magnets."

mercury; (*l*) is an arrangement to press upon the blade, and there is a screw (*m*) for regulating the height of the mercury.

A leaden weight (*o*) with a head of soft iron remains attached to the magnet, as long as the current passes through it, but when this is broken, the weight falls on to the end of the blade (*k*) over the cup, and presses the pin under the end of the blade into the mercury, thus completing a circuit through the screws (*f* and *g*).

**The disjuncter.** 16. In Fig. 7, Plate 26, are four pressure screws, *a*, *b*, *c*, and *d*, to secure the connecting wires; *e*, *f*, *g*, and *h* are small screws with platinum points, the point of (*e*) being presented to that of (*g*), and the point of (*f*) to that of (*h*). One electric current includes (*a*) and (*c*) passing from (*e*) to (*g*), and another circuit connected with (*b*) and (*d*) passes from (*f*) to (*h*). A trigger (*l*), capable of being cocked as shewn in the diagram, when released, moves in the direction indicated by the arrow, forces back the extremities of (*m*) and (*n*), which are straight springs holding (*e*) and (*f*), and by thus disconnecting these latter from (*g*) and (*h*), causes the simultaneous disjunction of the two electric currents.

**Arrangement of the gun, targets, screen, and voltaic batteries.** 17. The apparatus is placed in a small hut at a distance of about 130 yds. from the gun, so that it may not be affected by the firing; the electric currents are obtained by means of two of Bunsen's voltaic batteries *A* and *B* (Fig. 8, Plate 26), and the arrangement of the gun and targets is as follows:—The first target (*a*) Fig 8, is placed at a distance of 10 yds. in front of the muzzle of the piece, and the second target (*b*) 40 yds. beyond the former; both targets are of the same construction and dimensions, each consisting of a wooden frame, having copper wires stretched across in parallel rows by means of pins in the sides of the frame, and these wires are broken by the passage of the shot through them. In order to protect the wires of the first target from the action of the gas a wooden screen (*c*) is placed about 40 in. from this target between it and the gun; the screen has a circular hole (about 1½ calibres in diameter) through which the projectile passes.

**Operation of the instrument.** 18. The operation of the instrument is as follows (Fig. 8, Plate 26):—The gun is fired, the projectile passes through the first target, breaks the first circuit, and de-magnetizes the straight magnet of the pendulum; the bob begins to fall, carrying with it the index needle. When the projectile cuts the wires of the second target, the second circuit is broken, and the magnet of the conjuncture is thereby de-magnetized; the weight is thus released and falls into the cup, pressing down the blade with the pin underneath, which enters the mercury, and completes the third circuit. This last circuit magnetizes the

horse-shoe magnet of the pendulum, which therefore attracts the soft iron washer of the index needle, clamps it, and the arc of vibration may then be read off.

The time due to this arc of vibration can by the theory of the pendulum be readily ascertained, but it would be greater than the time taken by the projectile to pass from one target to the other; for, a certain small interval of time elapses between the rupture of the second circuit and the completion of the third circuit, viz. that due to the fall of the weight of the conjunctor. This small portion of time is found by means of the disjuncter, before the gun is fired, in the following manner:—The trigger of the disjuncter is released which, as before explained, separates the points (e) and (f) from those of (g) and (h) Fig 7, Plate 26, and thus breaks the two first circuits simultaneously; the bob of the pendulum falls, the index needle is clamped as before by the completion of the third circuit, and a small arc is thus obtained, which corresponds to the time the weight takes in falling; this small arc must be subtracted from that found when the gun has been fired, and the time then calculated will be that taken by the projectile to pass from one target to the other.

If  $A$  in Fig. 9, Plate 26, be the small arc found by operating with the disjuncter,  $A'$  that obtained when the gun is fired, then  $(A'-A)$  will be the arc of vibration of the pendulum during the time that the projectile is passing between the two targets.

Calculation of time.

19. In order to calculate the results of experiments expeditiously, a Table is formed shewing the times corresponding to the different arcs of vibration most probably required. A formula for the calculation of such a Table is obtained as follows:—Let  $l$  (Fig. 10, Plate 26), be the length of the pendulum beating the time  $t$  of one very small oscillation;  $v$ , the velocity of the centre of oscillation of the pendulum after a vertical descent  $h$ ;  $x$ , the variable angle of vibration. Then

$$v = \sqrt{2gh}$$

substituting for  $h$ , its value in terms of the constant angle of half-oscillation ( $75^\circ$ ) and of the variable angle  $x$ ,

$$v = \sqrt{2gl \{(\cos 75^\circ - x) - \cos 75^\circ\}}.$$

From the theory of the pendulum,

$$l = \frac{gt^2}{\pi^2};$$

$$\therefore v = \frac{gt}{\pi} \sqrt{2 \{(\cos 75^\circ - x) - \cos 75^\circ\}}.$$

Let  $T'$  be the time of describing the whole circle on the supposition of an uniform motion. Then

$$T' = \frac{s}{v} = \frac{2\pi l}{v},$$



and by substitution,

$$T = \sqrt{2 \{ (\cos 75^\circ - x) - \cos 75^\circ \}}.$$

Now if  $T$  be the time of describing an arc contained  $K$  times in the circumference,

$$T = \frac{T'}{R},$$

and 
$$T = \frac{2t}{K \sqrt{2 \{ (\cos 75^\circ - x) - \cos 75^\circ \}}}.$$

The value of  $t$ , in the instruments generally employed = .3342".

The distance between the targets divided by the time thus found will give the velocity of the projectile at the point of the trajectory equidistant between the targets ; but as the projectile will, in passing from the gun to this point, have lost a certain amount of velocity, a formula, somewhat similar to Dr Hutton's, given in Boxer's *Treatise* (page 33), is generally used to obtain the initial velocity.

Initial velocities from experiment.

20. The following Table of initial velocities is deduced from the results of experiments carried on<sup>1</sup> in Plumstead Marshes, in 1860—61, with Navez' electro-ballistic apparatus :—

Nature of Piece.	Charge.	Projectile.	Initial Velocity.
	lb. oz.	lb. oz.	ft. per sec.
Smooth-bored field pieces.	6-pr. gun .....	1 8	6 3-16 } solid shot.
	9-pr. gun .....	2 8	9 5-75 }
	12-pr. gun .....	4 0	12 10-5 }
	12-pr. how. ....	1 4	8 13 } common
	24-pr. how. ....	2 8	16 12 } shell.
Smooth-bored heavy ordnance.	18-pr. of 38 cwt.	6 0	17 11 }
	24-pr. " 50 "	8 0	23 8 }
	32-pr. " 58 "	10 0	31 6 }
	68-pr. " 95 "	16 0	66 4 }
	10-in. " 87 "	12 0	68 4 hollow shot.
Armstrong (rifled) 12-pr. ....	1 8	11 9	segmt. shell.

Velocity of recoil.

21. The elastic gas generated by the ignition of gunpowder, exerts an equal pressure in every direction ; consequently, when a gun is discharged, a force is impressed upon the bottom of the bore of the gun in the direction of the axis equal in amount<sup>2</sup> to that which acts upon the projectile. The momentum of the gun and carriage, is therefore equal to that of the projectile, both being acted upon by equal forces, and the velocity of recoil of the former may be found as follows :—

- If  $G$  = weight of gun,
- $C$  = do carriage,
- $w$  = do shot,
- $v$  = initial velocity of shot,
- $V$  = do. gun and carriage,

<sup>1</sup> By Captain Noble, R.A., under the Ordnance Select Committee.  
<sup>2</sup> Not strictly correct, see Boxer's *Treatise*, p. 35.

$$wv = (G + C)V,$$

$$V = \frac{wv}{G + C},$$

$v$  may be determined from the formula for finding the initial velocity of shot.

Or should the velocity of recoil of the gun alone be required;

If  $V'$  = initial velocity of recoil of gun,

$$V' = \frac{wv}{G}.$$

Comparison of velocities of recoil and strains upon carriages of two guns of the same calibre, but different weights.

22. If two guns have bores of the same calibre, but the weight of one gun is double that of the other, their respective velocities of recoil, and also the strains exerted upon their carriages, when fired with equal charges and similar projectiles, will be inversely as their weights.

If  $v$  = velocity of shot,

$w$  = weight of do.,

$W$  = weight of the 1st gun,

$W'$  = do 2nd „

$V$  = velocity of the 1st „

$V'$  = do 2nd „

The momentum of each gun will be equal to  $wv$ .

$$\text{but } V = \frac{wv}{W},$$

$$\text{and } V' = \frac{wv}{W'}.$$

or the velocities of recoil are inversely as the weights.

The work done by the guns in their recoil, and consequently the strains upon the carriages will be, as

$$WV^2 : W'V'^2,$$

or, by substituting the values of  $V$  and  $V'$ , as

$$\frac{v^2 w^2}{W} : \frac{v^2 w^2}{W'},$$

or the strains are inversely as the weights (see Art. 31, Lecture IV.)

#### *Resistance of the Air, and retardation of Projectiles.*

Resistance and retardation.

23. The “resistance which a projectile meets with in moving through the atmosphere depends chiefly upon its velocity, the magnitude of the surface it presents to the resistance, and its peculiar form.<sup>1</sup> In the case of ordinary spherical projectiles, supposing the resistance to vary as the square of the velocity, if  $d$ =the diameter of a ball, and  $v$ =its velocity, the resistance opposed to its motion will be as

$$d^2 v^2.$$

<sup>1</sup> This subject is treated in a more general manner in Boxer's Treatise, p. 107.

From this ratio and with the help of Hutton's Table (Boxer, p. 102) of experimental resistances to a 2-inch ball, the amount of resistance to any other ball can be ascertained. If the resistance  $R$ , to a 68 lb. ball, of 8 inches diameter, and moving with a velocity of 1600 feet per second be required.

From the table the resistance to the 2-inch ball at this velocity is = 68 lbs. nearly

$$\therefore 2^3 : 8^3 :: 68 : R,$$

$$R = 1088 \text{ lbs.}$$

The velocity it loses in consequence of this resistance, or its "retardation," will, however, depend also upon its weight, being in fact, inversely as the weight, and the weight is proportional to the cube of the diameter, so that the retardation of the ball will be as

$$\frac{d^3 v^3}{d^3}.$$

Large projectiles less retarded than small ones of equal density.

24. If two shot of different diameters are fired under similar circumstances, that is, supposing the angles of elevation of the guns from which they are respectively fired are the same, the initial velocities equal, and the densities of the shot alike (for instance, should they be two cast-iron solid shot), it appears from what has just been said, that the shot of the largest diameter will range to a greater distance than the other, the resistance to each being as  $d^3$ , whereas the retardation is inversely as  $d^3$ ; consequently, for equal ranges, the elevation of the piece from which the larger shot is fired may be reduced, and the chance of its striking the object fired at will therefore be greater than that of the smaller ball, the trajectory of the latter being more curved.

Retardation of projectiles of different densities.

25. If a shell and solid shot of equal diameters, but the densities of which are of course different, be fired consecutively from a gun, at the same elevation, and with equal charges, their initial velocities will be inversely as the square roots of their respective weights (Art. 8), the velocity of the shell being therefore the greatest; the shell will however, in consequence of its inferior weight, be more retarded by the resistance of the atmosphere than the shot, so that, although at short ranges, when firing shell, the elevation of the gun would be rather less than when firing solid shot, still at long ranges the elevation would be about the same, whether shot or shell were fired, or would be even less for the shot. For instance, it was found by actual practice, in the Woolwich marshes, that at a range of 1400 yards, the 32-pr. gun of 56 cwt. required about the same elevation whether shot or shell were fired, but at 1000 yards the shell required about one-fourth less than the shot.<sup>1</sup> In the Tables of

<sup>1</sup> The service charge of 10 lbs. used with both shot and shell.

Ranges given in the *Hand-Book for Field Service*, the ranges of the shell for the same gun are greater than those of the shot up to 5° of elevation, when they are both equal, viz. 1910 yards, after which the ranges of the shot exceed slightly those of the shell.

26. If balls of equal diameters but of different weights or densities, as solid shot and shell, are fired from the same gun with charges bearing the same proportion to their respective weights, their initial velocities will be equal,<sup>1</sup> as will appear from the formula for initial velocity (Art. 10). The ranges at "point blank" or small elevations will not differ to any great extent, but at angles of elevation giving long ranges, the times of flight for which will be considerable, the retardation of the denser ball will be much less than that of the lighter, and consequently it will range to a greater distance.

Elongated  
projectiles less  
retarded than  
balls.

27. If an elongated projectile and a ball of equal weight be fired with the same initial velocity and angle of elevation, the former will be less retarded, and will consequently range further than the ball; for, the diameter of the elongated projectile being smaller than that of the ball, the elongated projectile will not oppose so great a surface to the resistance of the air as the ball.

For instance, if a 12-lb. Armstrong projectile and a 12-lb. ball be moving with the same velocity, the resistance of the air may be assumed to vary as the squares of their respective diameters.

The diameter of the 12-lb. Armstrong projectile = 3-in.  
do. ball = 4·5-in.

∴ resistance will be as 9 : 20·25  
or — 1 : 2·25.

Advantages as  
regards range  
if lengthening  
projectiles.

From this it appears that the resistance opposed to the ball is more than twice that which acts against the Armstrong projectile; and this comparison though rough (for the obliquity of the axis,<sup>2</sup> and the form of the point of the elongated projectile are not considered) is sufficiently accurate to account for the results obtained in practice. As the elongated projectile is lengthened, its weight remaining the same, so will its diameter decrease and its range be increased.

Comparison of  
range in air,  
and in vacuo.

28. The following Table and remarks will shew clearly the extent to which the range of an ordinary projectile fired with a high velocity is decreased by the resistance it meets with from the atmosphere :—

<sup>1</sup> Any difference would arise from the charges not being of equal length.  
<sup>2</sup> This point will be discussed in the next Lecture.

*Ranges of a 32lb. shot, fired with an initial velocity of 1600 feet per second, in vacuo and in air.*

1°	2°	3°	4°	Elevation
yds. 930 780 1·19	yds. 1840 1160 1·58	yds. 2788 1460 1·90	yds. 3700 1690 2·19	Range in vacuo Do. air Ratio.

From this it appears that at 1° the range in vacuo exceeds that in air by about  $\frac{1}{3}$ th, but at 4° the former is more than double the latter.

Maximum  
range.

29. The maximum range of a projectile, fired with a given initial velocity in vacuo, would be obtained at an angle of 45° of elevation; for, from equation (2) Art. 2 of this Lecture it appears, that  $R$  varies as  $\sin 2a$ , and  $R$  will therefore be greatest when

$$2a=90 \text{ or } a=45^\circ.$$

In the air, however, the resistance increasing with the velocity, as the latter is greater the angle of elevation to give the maximum range decreases, for the trajectory will differ more from a parabolic curve. With high velocities such as 1600 ft. a second, the angle to give the maximum range in the air is found both by theory and practice to be about 32°<sup>1</sup>; a 56 lb. shot fired with a charge of 16 lbs. giving an initial velocity a little higher than 1600 ft., ranged at this angle 5720 yds.; in vacuo the range at 32° would have been 23,946 yds., and at 45°, 26,666 yds.

Trajectory of a  
projectile in the  
atmosphere.

30. Fig. 2, Plate 24, will give some idea of the trajectory of a projectile as modified by the resistance of the atmosphere.

If projected in vacuo, the shot would pass through the points  $A, B, C, D$ , but in the atmosphere through  $a, b, c, d$ ; in the latter case the space passed over in any second by virtue of the force of projection is less than that passed over in the preceding second in consequence of the resistance of the air; but this decrease of space is less as the velocity diminishes, until at last when the velocity has become very low it would be so slight, that the progressive motion in a horizontal direction (until the shot graze the earth) may then be considered uniform.

31. Some experiments were carried on in Russia by Colonel Mayefski, of the Russian artillery, in 1858, and the actual trajectories of projectiles, fired from a cannon of tolerably large calibre under different circumstances, that is with different charges and elevations, were determined. The trajectories were also calculated by formulæ somewhat similar to those given by Gen. Didion, the calculated and actual results agreeing very nearly as will appear by the Table opposite. It is not intended to

<sup>1</sup> Art. 93, p. 63, Sir H. Douglas' Naval Gunnery.

explain these formulæ,<sup>1</sup> but to give the Table of Results, and to make from it a few useful deductions applicable to a certain extent to the trajectories of projectiles fired from some of the service ordnance.

For these experiments a bronze “canon de 24” was used, and the ordinates of the trajectories of the projectiles fired were ascertained, by their passage through wire screens stretched across the range at different distances. The velocities of the projectiles at a fixed distance from the muzzle of the gun were obtained by means of the electro-ballistic apparatus of Captain Navez. The mean weight of the projectiles fired was 26·69 lbs. (Eng.), and the mean diameter 5·868 in.

The following Table will shew the results of the experiments :—

Charge.	No. of rounds.	Elevation.	Initial velocity.	Ordinates at distances of									
				yds. 12	yds. 116	yds. 233	yds. 350	yds. 466	yds. 583	yds. 700	yds. 816	yds. 933	yds. 1050
lbs.	dg.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	
8 23 1½	1731	{ 1·116 1·119	10·10	18·85 18·45	24·67	28·68 28·51	29·42 26·90	26·90	20·33	9·76 10·	5·47 5·3	} Obs. } Cal.	
5 23 2	1367	{ 1·301 1·29	11·56	20·76 20·07	26·27	28·43 28·27	27·02 19·69	9·49	10·31				
3 25 2½	1073	{ 1·611 1·61	14·06	24·37 23·70	29·85	30·64 29·92	25·47 14·76	2·43 2·28	} Obs. } Cal.				
1·5 22 3½	713	{ 2·217 2·23	18·03	27·33 27·01	27·48	17·41 17·74	} Obs. } Cal.						
75 22 5½	453	{ 3·417	25·07 25·16	30·06 29·85	13·41 12·98								

In the original Tables given in the “Occasional Papers of the R.A. Institution (Nov. 1859),” the ranges are in *sagènes*, one of which is equal to 7 English feet.

32. As the first trajectory in the Table, viz. that obtained with a charge of 8 lbs., and an elevation of 1½°, approaches in all probability very nearly to those of shot fired from a service 32-pr. (56 cwt.) and 24-pr. (50 cwt.) with service charges, and the same elevation of 1½°,<sup>2</sup> it may be instructive to place this trajectory on paper (Plate 26) in order to find the angle of descent of the shot, and the distance through which it passes within 6 ft. of the ground; this latter point is of great practical importance.

Angle of descent.

The angle of descent is readily found from the triangle *ABC* (Fig. 2, Plate 26), as the trajectory will not differ sensibly from the straight line joining *AC*; for *BC* = 116 yards, *AB* = 9·76 + 5·47 ft. = 15·23 ft., or about 5 yds; and if (*a*) be the angle of descent

<sup>1</sup> The equations for the trajectories of balls when the resistance of the atmosphere is taken into account, is given in Boxer's Treatise, Art. 268, p. 131, and an example is worked out, shewing the calculated ordinates at distances of 100 ft. apart.

<sup>2</sup> Range of shot from 32-pr. (56 cwt.), with charge of 10 lbs. and 1½° elev. is about 1060 yds.

” 24-pr. (50 cwt.), ” 8 lbs. do. 1030 yds.  
28

$$\tan a = \frac{5}{116},$$
$$a = 2^{\circ} 28'$$

Extent of  
ground covered.

From (Fig. 1, Plate 26) we find that 45 yards of ground are covered by the shot (at a height of 6 ft. from the ground) before grazing; the ground line in this Fig. is placed 4 ft. below the horizontal line *AB*, passing through the extreme point of the axis at the muzzle of the gun, this being about the height to which the carriage would raise the piece above the ground. As the angle of ricochet would be less than the angle of descent, in consequence of the ball striking the ground a comparatively non-elastic substance, more than 40 yds. would most probably be covered after the graze,<sup>1</sup> so that it may be concluded with tolerable certainty, that for about 100 yds. the ball would pass within 6 ft. of the ground.

Vertical distance of point upon which the axis of the gun was directed.

The vertical distance of the point above the ground upon which the axis of the gun was directed may also be found.

If (*x*) be the vertical distance,

$$x = 1044 \times \tan 1\frac{1}{4}^{\circ}$$
$$= 31.842 \text{ yds. or } 95.526 \text{ ft.}$$

Formula for finding remaining velocity.

33. Hutton's formulæ for finding the "final or remaining velocity" of ordinary shot or shell, when fired from a gun at low elevations, gravity not being considered, are given by Boxer (pp. 120, 121), as well as the investigations upon which they are based.

For projectiles of different specific gravities, the formula is

$$x = \frac{w}{32md^3} \times \log_{\frac{V - \frac{n}{m}}{v - \frac{n}{m}}},$$

- in which *d* = diameter of ball in inches,
- w* = its weight,
- V* = the initial velocity,
- v* = the velocity of the ball after moving through the distance *x*,
- x* = range (in feet),
- $\left. \begin{matrix} n = .00175 \\ m = .000007565 \end{matrix} \right\}$  coefficients depending upon the distance of the air.

If  $q = \frac{n}{m} = 231,$

and the log<sup>e</sup> be reduced to log<sub>10</sub> by multiplying by 2.30258, the equation will then be

$$x = 2.30258 \times \frac{w}{32md^3} \times \log_{10} \frac{V - q}{v - q} \dots\dots\dots (1)$$

<sup>1</sup> This is supposing the practice to take place on level ground; the angle of ricochet will of course depend upon the nature of the ground or substance upon which the ball strikes, and the velocity of the ball will be but slightly reduced by the graze at this low angle.

*On the Penetration of Projectiles.*

Circumstances  
upon which  
penetration  
depends.

36. The penetration of a projectile depends upon a variety of circumstances, such as its velocity at the moment of impact, its density, diameter, nature of the object struck, and the relative position of this latter with regard to the trajectory or path of the projectile.

37. Various formulæ have been given to express the penetration of projectiles; the following are taken from Sir Howard Douglas' work on *Naval Gunnery* :—

$$p = \frac{2v^2r\delta}{8Rg}$$

is a formula expressing the depth to which shot, on striking with a given velocity will penetrate into an object whose resisting force is supposed to be known.

In this formula,

$p$  = depth penetrated,

$v$  = velocity of the shot at the instant of striking,

$r$  = the semi-diameter,

$\delta$  = the density of the shot,

$g$  = force of gravity (32.2 ft.)

If the above formula be put in the form

$$p = \frac{2v^2r\delta g}{8Rg^2},$$

the specific gravity of the shot may be substituted for  $\delta g$ . The value of  $R$  must be determined by experiment.

When the resisting material is the same

$p$  varies as  $rv^2\delta$ ..... (a),

also when shot of the same density is used, and the resisting material the same

$p$  varies as  $rv^2$  ..... (b)

or, in the last case, the depth penetrated varies with the diameter of the shot, and with the square of the velocity at the instant of striking: it appears from (a) that in order to obtain great penetration, balls of large diameter and great density should be employed, especially as such balls will be less retarded by the resistance of the atmosphere than smaller balls of even the same density (Art. 24), and so will have greater "final" or remaining velocity. From the hypothesis of M. Poncelet, that the resistance of a material struck by a shot is proportional to the square of the diameter of the projectile, and from a comparison with the results of experiment, it has been found (*Experiences d'Artillerie Exécutees à Gavre*, Chap. 21, Sect. 3) that the depth of penetration into oak, may be expressed by a formula; which when transformed so that the penetration shall be obtained in English feet; is,



$$p=4.612r\delta \log \left(1 + \frac{v^2}{1076696}\right) \dots\dots\dots (c)$$

$v$  being, in feet per second, the velocity of the shot at the time of impact,  $r$  the semi-diameter of the shot in decimals of a foot, and  $\delta$  the specific gravity of the shot,—that of water being unity. The volume of the space penetrated by a shot into any material is frequently represented by the *vis vivâ* or active force of the shot in motion, in which case it is proportional to the product of the mass of the shot, multiplied by the square of its velocity; that is,  $w$  representing the weight of the shot,  $v$  its velocity, and  $g$  ( $=32.2$ ) the force of gravity; the volume of penetration varies with  $\frac{w}{g} v^2$ , or  $r^3 v^2 \delta$ ,  $r$  being the semi-diameter, and  $\delta$  the density (for which may be substituted the specific gravity) of the shot; it varies with  $r^3 v^2 \delta$ . The coefficient in the formula (c) is conformable to the recent experiments indicated in the "*Aide Memoire d' Artillerie Navale.*" Paris, 1850.

An example is here given to shew how this formula (c) may be applied.

If a solid shot be fired from a 32-pr. gun 56 cwt. with a service charge, at a block of oak 450 yds. distant, to what depth will it penetrate, specific gravity of the shot (cast-iron) being 7.2?

By formula for initial velocity, Art. 10,  
 $V=1600.$

By formula (2) for final velocity. Art. 30,  
 $v=1170,$

$v = 1170$  ft. or velocity at moment of striking,  
 $r = .25$  ft. or radius of shot in decimals of a foot,  
 $\delta = 7.2$  specific gravity of shot,

$$p=4.612r\delta \log \left(1 + \frac{v^2}{1076696}\right),$$

$$p=4.612 \times .25 \times 7.2 \times \log \left(1 + \frac{1170^2}{1076696}\right) \\ = 3 \text{ ft. } 36 \text{ inches.}$$

If we refer to the Tables of Penetration following, the penetration of a shot from the French 24-pr., 6 inch cal., at 450 yds. is about 44 inches, and of a shot from the American long 32-pr. at 500 yds. is 38.7 inches.

The differences between those depths laid down in the Tables, and that found by computation will necessarily arise from a variety of circumstances, upon which the coefficients in the formula depend, as the quality of the wood, the strength of the powder, the windage of the gun, &c.

French experi- 38. The French have made many experiments in penetration; ments. those carried on at Metz, in 1834, were made on rough hewn stone of good quality. In these experiments the holes formed in

the masonry by balls fired perpendicularly to it, and at short distances, were in the shape of a funnel externally, whose mean diameter was about five times that of the shot; internally, the form of the hollow was nearly cylindrical. The shape of the internal portion appears to have been produced by the re-action of the masonry, of which some pieces were projected to a distance of from 40 to 50 metres. Round the opening, a cracking or rending of the masonry took place, which separated the stones, and which was about half as large again in diameter as the opening, viz.

	1·15 metres for the 24-pr.
	·9 ..... 16-pr.
and	·8 ..... 12-pr.

Nearly all the balls were broken, being fired with a charge of one-fourth their weight. The effect of shells against masonry was scarcely perceptible. They broke at the moment of impact; or when fired with small charges made but feeble impression. From experiments made at the same period with regard to the penetration of shot into iron, it was found that masses of cast-iron above one yard square, and thirteen inches thick do not resist the shock of balls fired against them, with even moderate velocities, having been fractured, not only at the point of impact, but also at points considerably removed from them.

Penetration of  
shot into the  
side of a vessel.

39. The penetration of projectiles is of the greatest importance when the destruction of shipping is taken into consideration. For instance, should a shot lodge in the side of a ship without having sufficient momentum to force its way through, little or no present damage will be sustained, nor will the vessel be obliged to retire from action, whatever repairs she may afterwards have to undergo. A shot to be really effective against a vessel, must have enough terminal momentum to break through its side, and it has been shewn, that to produce the greatest damage it should lose all motion, just as it ceases to be resisted by the wood; this takes place when the shot has forced its first hemisphere out of the further side. It cannot, however, be expected that such precision as this would be obtained in practice, for the slightest alteration in the range, angle of impact, &c. would quite upset any such calculation.

Comparative  
penetration of  
shot of different  
calibre, also of  
shot and shell.

40. It has already been shewn in Art. 37 of this Lecture (a), that the greater the calibre of shot, the density, elevation, and initial velocity being equal, the greater will be the penetration: also that the penetration of a solid shot is greater than that of a shell or hollow shot of equal diameter, when they are fired with the same elevation, and with equal initial velocities.

41 The following Table of the relative penetrations of solid

and hollow shot is taken from Simmons' *Discussion on the Armament of the Navy*:—

*Comparative Effect of the 48 lb. Hollow Shot from the 8-in. gun of 65 cwt., Charge 12 lbs., Windage '1; and the 32-pr. Solid Shot (weight of gun, 56 cwt.), Charge 10 lb. 11 oz., Windage '203.*

Range in yards.	Velocity per Second.		Range in yards.	Relative Penetrating Force.	
	48 lbs. 8-inch Shot.	32-pr.		48 lbs. 8-inch Shot.	32-pr.
Initial Velocity. }	1690	1730			
Remaining velocity at a range of {			Relative penetrating force at {		
500	1092	1200	500	51.136	68.302
800	877	1001	800	32.983	47.572
1000	765	883	1000	25.096	36.983
1200	672	783	1200	19.365	29.060
1500	562	661	1500	10.544	20.742
2000	436	515	2000	8.152	12.873
2500	358	418	2500	5.406	8.287
3000	310	354	3000	4.121	5.944

### Causes of errors in tables of penetration.

42. Discrepancies will constantly be noticed in Tables of Penetration, proceeding probably from the following causes:—

- (1) The difference of shape in projectiles of the same calibre arising from the difficulty of casting them exactly similar.
- (2) Irregularities in the elasticity and density of the materials against which the projectiles are fired.
- (3) The liability of the propulsive power to very distinct variations in its intensity; not only from the powder being made at different manufactories, but also from the state of the atmosphere and other minor circumstances; and
- (4) The impossibility of ensuring that the path of the projectile shall always make exactly the same angle with the surface of the object struck; this angle being generally taken as a right angle.

### Tables of penetration.

43. The following Tables of the penetration of shot and shells are taken from the experiments at Metz, carried on in 1834.

### *Table of Penetration of Mortar Shells.*

(English Measures).

Angle of Elevation.	Range.	Penetration in								
		Rammed earth.			Oak.			Masonry.		
		8-in.	10-in.	12-in.	8-in.	10-in.	12-in.	8-in.	10-in.	12-in.
	yds.	in.	in.	in.	in.	in.	in.	in.	in.	in.
30°	704	7-87	17-72	19-68	3-93	7-87	8-66	1-96	3-54	3-98
	1408	13-77	25-59	27-51	6-96	11-19	13-77	3-54	4-72	5-11
45°	704	11-19	19-65	21-68	5-90	9-84	10-52	3-14	3-93	4-32
	1408	16-72	27-51	29-52	7-87	13-77	16-72	2-63	5-51	5-90
60°	704	17-72	29-59	31-49	8-66	13-99	14-56	4-23	5-90	6-29
	1408	19-65	31-49	33-46	9-84	13-77	15-72	4-72	6-29	6-66

Penetration of Projectiles from Guns and Howitzers.  
(English Measures.)

Calibre.		Charge.	Distance in yards.								
			55	100	219	328	438	656	875	1094	
			In good rubble Masonry.								
pr.	in.		in.	in.	in.	in.	in.	in.	in.		
36	6-796	...1rd	26-4	25-6	23-8	22-2	20-8	17-9	15-0	12-2	
24	6-011	{1rd	2-38	22-8	21-1	19-5	18-1	15-2	12-2	9-8	
		{1th	22-2	21-5	19-9	18-2	16-7	13-8	11-2	9-1	
		{1th	19-7	18-9	17-3	15-7	14-4	11-8	9-7	7-9	
16	5-264	{1rd	20-7	19-7	17-9	16-3	14-8	11-8	9-2	7-3	
		{1th	19-1	18-2	16-7	15-2	13-8	10-8	8-5	6-7	
		{1th	16-7	16-1	14-6	13-0	11-6	9-1	7-3	5-9	
12	4-775	{1rd	18-5	17-5	15-9	14-6	13-0	10-0	7-7	6-1	
		{1th	17-3	16-5	15-0	13-4	11-8	8-9	6-9	5-5	
		{1th	15-6	14-8	13-2	11-6	10-2	7-5	5-5	4-1	
8	4-175	...1rd	15-6	14-8	13-2	11-6	10-2	7-5	5-5	4-1	
In sound Oak Wood.											
36	.....	...1rd	64-2	62-2	58-3	54-3	50-8	44-1	37-4	31-5	
24	.....	{1rd	57-9	55-9	51-6	47-6	44-1	37-4	30-7	24-8	
		{1th	55-3	52-3	48-4	44-9	41-3	35-0	28-4	22-6	
		{1th	48-4	46-5	42-9	39-4	36-2	29-5	24-0	19-2	
16	.....	{1rd	50-0	48-0	43-7	40-2	36-6	29-9	23-6	18-5	
		{1th	46-5	44-5	40-9	37-4	33-9	27-6	21-7	16-1	
		{1th	41-4	39-8	36-2	32-7	29-5	23-2	17-7	14-2	
12	.....	{1rd	44-9	42-9	38-6	35-0	31-9	25-6	19-7	14-6	
		{1th	42-1	40-2	36-6	33-1	29-9	23-6	18-1	13-4	
		{1th	38-2	36-2	32-3	28-7	25-6	19-2	12-8	10-6	
8	How.	lb.	27-6	26-0	22-4	19-2	16-5	10-0	10-6	9-1	
		{4-4	15-4	14-2	12-6	11-4	10-2	8-7	7-9	7-5	
		{2-2	31-9	30-3	26-8	23-6	20-5	15-0	11-8	9-8	
24	.....	{2-2	26-8	25-2	21-7	18-5	15-8	11-4	9-1	7-9	
		{2-2	26-8	25-2	21-7	18-1	15-0	10-2	7-9	6-2	
		{2-2	26-8	25-2	21-7	18-1	15-0	10-2	7-9	6-2	
In compact earth, half sand, half clay.											
36	.....	...1rd	106-8	102-4	97-3	93-4	89-4	82-3	75-6	69-7	
24	.....	{1rd	97-7	92-6	85-9	81-1	77-2	70-1	63-8	58-3	
		{1th	90-2	86-7	81-5	77-6	74-0	67-3	61-8	57-1	
		{1th	83-5	79-6	73-6	69-3	65-8	59-9	54-4	49-2	
16	.....	{1th	78-3	75-2	69-7	66-5	63-4	57-9	52-4	47-3	
		{1th	63-4	59-9	54-7	50-8	48-2	42-9	38-6	35-0	
		{1th	59-1	55-9	52-0	48-8	46-1	41-3	37-4	33-9	
12	.....	{1th	54-7	52-0	48-9	43-3	40-2	35-4	31-9	28-7	
		How.	lb.	47-3	45-3	41-7	38-0	35-4	30-3	26-0	22-2
		{4-4	41-7	40-2	37-0	33-9	31-1	27-2	24-0	21-7	
8	.....	{2-2	51-2	48-8	45-0	41-0	37-4	30-7	25-2	22-1	
		{2-2	44-1	42-5	38-6	35-0	31-9	26-4	22-4	19-7	
		{2-2	42-9	41-0	36-6	32-7	29-1	23-2	18-9	16-1	

44. The penetrations in masonry of medium quality are one-fourth greater than those given in the Tables; and in brickwork three-fourths greater. The penetrations into light earth are one-half greater than the tabular quantity; if fresh heaped, nearly double. The penetration into elm is one-third greater, and into pine or birch-wood, three-fourths greater than into oak. From the French experiments at Gavre, in 1836, it was found that a projectile will not lodge in a mass of timber unless it penetrates to a depth nearly equal to its diameter; as the elasticity of the fibres will force the shot or shell out, if the

penetration be not deep enough to allow them to close behind the projectile, and so keep it imbedded in the wood.

Penetration  
into water.

45. In 1848, experiments were made to try the penetration of shot into water, when fired with small angles of depression towards its surface; upon the results of these experiments, Sir Howard Douglas has the following remark:—"In consequence of the loss of force which the balls, in all these experiments sustained, it has been inferred, that if a shot be fired with such a depression as a ship's gun will bear, it will not penetrate into water more than 2 ft.; and, consequently, that it will be impossible to injure a ship by firing at her under water. The correctness of this inference we must however be permitted to doubt, till further experiments have been made. It is highly probable that conoidal shot would penetrate to a certain depth into the water, and strike the ship below the water line."

This opinion of Sir H. Douglas has been borne out by later experiments. An elongated projectile fired from a Whitworth gun passed through 33 ft. of water, and then penetrated into the side of a ship through 12 or 14 in. of oak beams and planking. From this it appears that elongated projectiles would prove very destructive to ships, when fired at short ranges, so that they may strike considerably below the water line, for the plugging of such perforations would be very difficult, if not impossible. In order that the elongated projectile may penetrate the water, and not ricochet from its surface, its longer axis must be tangential or nearly so to the trajectory.

American  
experiments.

46. The following Tables are extracted from Dahlgren's work on *Shells and Shell Guns*.

*Penetration in a Mass of seasoned White Oak of Shot and Shells, fired from U.S. Navy Ordnance.*

Gun.	Charge.	Projectile.	Initial Velocity.	Penetration, &c.			
				500 yds.	1000 yds.	1500 yds.	2000 yds.
	lbs.		ft.	in.	in.	in.	in.
18-pr. long.....	6	Shot	1790	28-9	17-9	11-0	6-9
24-pr. do. ....	8	...	1790	33-6	21-8	14-1	9-3
32-pr. of 32 cwt. ...	4½	...	1250	26-4	19-5	12-7	8-8
32-pr. of 42 cwt. ...	6	...	1450	32-0	22-0	15-0	10-3
32-pr., long .....	9	...	1700	38-7	26-5	18-2	12-5
42-pr. ....	10½	...	1690	41-7	29-7	21-1	15-1
64-pr. ....	16	...	1620	49-9	37-8	27-9	20-8
8-in., 55 cwt. ....	7	Shell	1350	29-2	20-0	14-0	9-7
8-in., 68 cwt. ....	9	...	1500	33-2	23-0	15-9	11-0
10-in., 86 cwt. ....	10	...	1160	32-1	24-2	18-2	13-7

"The quantities thus assigned are to be considered as representing only the mean penetration of balls, in firing a series of them into a target."

47. The following Table gives the thickness of the sides of French ships of war, of all rates.

(From the Aide Memoire Navale.)

Classes of Vessel.		Thickness					
		at lower port-sills of				at	
		Spare Deck.	Upper Deck.	Main Deck.	Lower Deck.	Water Line.	Orlop Deck.
		inch.	inch.	inch.	inch.	inch.	inch.
Line of Battle Ships.	1st Rate ...	18-12	20-48	23-23	31-11	32-20	33-27
	2nd do. ...	18-12	...	22-64	30-72	31-9	33-47
	3rd do. ...	17-33	...	21-27	28-75	29-23	31-11
	4th do. ...	17-33	...	20-09	26-39	26-58	27-37
Frigates.	1st Class ...	16-23	...	...	23-63	24-81	25-6
	2nd do. ...	15-75	...	...	21-66	22-84	23-63
	3rd do. ...	14-57	...	...	18-51	20-09	21-27
Corvettes (4 gaillards).....		13-39	...	...	16-54	16-93	18-9
Brigs of 20 guns .....		13-78	...	...	...	13-78	15-75

“ With such variant capacity for resistance, it will be perceived that the effect of artillery upon ships must be exceedingly unequal, and altogether different from those produced by the same projectiles upon solid targets.”

Effect of shot upon cast and wrought-iron.

48. Experiments have during the last few years been carried on both at Woolwich and Portsmouth, for the purpose of ascertaining the effect of shot upon plates or slabs of iron, both cast and wrought. Sir H. Douglas gives the following results of experiments carried on at Portsmouth, in 1854. “ During the months of September and October, 1854, some experiments were carried on at Portsmouth, in order to try the capability of wrought-iron slabs to resist the impact of solid and hollow shot, and the following are the results :—the target was a section of a frigate covered with wrought-iron plates, 4½ inches thick, and the projectiles employed were 32-pr. and 68-pr. solid shots, and 8-inch and 10-inch hollow shots. At 400 yds. the 32-pr. solid shot, and the 10-inch and 8-inch hollow shot, merely indented the target to the depths respectively of 1½, 2½, and 1 inch; but the 68-pr. solid shot, being fired with 16 lbs. of powder, penetrated the plates. These were always split at the bolt-holes, which were about one foot asunder; and in consequence, it was recommended that they should be bored as far apart as possible. The conclusion drawn from the experiment was, that 4½-inch iron plates, applied as a covering to ships, would give protection during an action against 8-inch and 10-inch hollow shot, and against 32-pr. solid shot, but very little against solid shot of 68 lbs.”

49. Experiments were carried on at Woolwich, in 1858, in order to ascertain the resistance which blocks of cast-iron 2½ feet thick, and plates of wrought-iron 8-inches thick, would offer to projectiles fired from the service 68-pr., it being supposed that

land batteries might be strengthened with such masses of iron. The results of these experiments were generally considered unfavourable to the employment of iron, either cast or wrought, for strengthening batteries.

Some experiments were made at Shoeburyness, in 1860, with an embrasure constructed of Thornycroft's rolled iron, which resisted the fire of projectiles from both smooth-bored and rifled guns successfully. The embrasure was built up of a number of slabs of iron 10 inches thick, each slab having a mortice on one face and a tenon on the other; the slabs could therefore be fitted together and these were secured by iron ties and rods. The iron was at first supported behind by stone-work, but this latter was afterwards removed, for it appeared to add but little to the strength of the embrasure, while it contracted the interior space, and the splinters from it might prove destructive to a gun detachment<sup>1</sup>. This kind of embrasure is comparatively inexpensive, the slabs requiring but little labour to bring them to the desired form.

Penetration of  
elongated  
projectiles.

50. The penetration of an elongated projectile is greater than that of a spherical shot of equal diameter and of similar density, if they are both fired with equal initial velocities, and at the same angle of elevation; for, the weight of the former being so much greater than that of the spherical shot its penetration will be greater by (a) Art. 37 of this Lecture, and also it will be less retarded Art. 23, and have a greater final velocity, the penetrations being as the squares of their respective velocities at the moment of striking. In general, however, an elongated projectile is fired with a lower initial velocity than a ball of equal weight from a smooth-bored gun, and therefore at a short distance the latter will most probably produce more effect as regards penetration than the former; but as the range is increased so will the penetrating power of the elongated projectile be greater compared with that of the ball, for the former will maintain a high velocity much longer than the ball. It is only at very short ranges such as 500 or 600 yds. that the fire of a smooth-bored gun is sufficiently accurate to allow of a comparison of its results with those obtained from practice with a rifled gun; beyond such ranges the accuracy of a smooth-bored gun cannot be depended upon, and the total effect produced by a number of balls upon an object would most likely be inconsiderable; but with a rifled gun the blows of its elongated projectiles can be repeated on the same part of the object at much longer ranges, and a wall or side of a ship could therefore be battered with effect at ranges where balls would be practically useless. The

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<sup>1</sup> Report of Ordnance Select Committee, p. 330 of "Proceedings of the Royal Artillery Institution."

pointed form of the fore part of the elongated projectile assists no doubt in increasing its penetration into substances such as earth or sand, but it is found that for penetrating very hard substances as wrought-iron plates, a flat-headed projectile gives the best results, punching a hole completely through a plate which would defy the more pointed projectile. Some small projectiles of cylindrical form lately tried against iron plates gave very excellent results, punching clean holes of the same diameter as the projectile. Flat-headed projectiles had no advantage when fired against Thornycroft's slabs of iron, but it was found that the fore part of a projectile of such form spread out after making only a slight indentation. In order to obtain penetration into an iron slab or plate the thickness of the metal must bear a certain proportion to the momentum of the projectile, and as the velocity of the latter is increased, its diameter and weight remaining the same, so will its penetrating power be greater; in fact, increase of velocity will be of more advantage than greater weight, as regards mere penetration. (a, Art. 37.)

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## GUNNERY.

[Continued].

*Deviations of Projectiles from Smooth-bored Ordnance.*

1. VERY great irregularities occur in the paths described by projectiles fired from smooth-bored ordnance. It is a fact, well known to all practical artillerymen, that if a number of solid shot (or any other projectiles) be fired from the same gun, with equal charges and elevations, and with gunpowder of the same quality, the gun carriage resting on a platform, and the piece being laid with the greatest care before each round, very few of the shot will range to the same distance; and, moreover, the greater part will be found to deflect considerably (unless the range be very short) to the right or left of the line in which the gun is pointed. This will appear evident by an inspection of Tables, deduced from the results of the most careful experimental practice.

Cause of  
deviation.2. The principal causes for these deviations are,<sup>1</sup>

- (1) Windage;
- (2) The imperfect form and roughness of surface of shot;
- (3) Eccentricity of projectile arising from a want of homogeneity.

Windage causes irregularity in the flight of a projectile from the fact, of the elastic gas acting in the first instance on the upper portion of the projectile, and driving it against the bottom of the bore; the shot re-acts at the same time that it is impelled forwards by the charge, and strikes the upper surface of the bore some distance down, and so on, by a succession of rebounds, until it leaves the bore in an accidental direction, and with a rotatory motion, depending chiefly on the position of the last impact against the bore.

3. Thus, should the last impact of a (concentric) shot when fired from a gun be upon the right-hand side of the bore, as represented in Fig. 1, Plate 27, the shot will have a tendency to deflect to the left in the direction *b*, while at the same time, a rotation will be given to it in the direction indicated by the arrows; the effect of this rotation will however cause the ball, during its flight, to bear off gradually to the right, so that the

<sup>1</sup> Wind affects projectiles from rifled bores, and is not therefore mentioned here. The deviation caused by the rotation of the earth may be practically disregarded, for it would only be sensible in very long ranges, and in these the disturbing effects of different currents of air during a long time of flight, would quite upset any calculation for such deviation.

deflection will not be to the left, but to the right, unless the range be short. Many explanations have been given to account for the effect produced upon the trajectory by the rotation of the shot, but the most satisfactory are those of Robins and Magnus, which are accordingly inserted here.

In order to simplify the question, the only case fully explained will be, when the shot is rotating as above (Fig. 2, Plate 27), but it will be evident that the following remarks would equally apply to a ball striking the bottom of the bore, when the rotation of the fore part would be from above downwards, and instead of deflecting to the right, the range of the ball would be decreased, as shewn by (*d*). Suppose the ball to rotate in an opposite direction the results would be reversed, that is to say,—if a fig. represented a rotation imparted by the ball having impinged on the left side of the bore, the deflection would be to the left; but should the same fig. shew a rotation caused by an impact on the top of the bore, the range would be increased. Should the shot on leaving strike any intermediate part of the bore, a compound effect would be produced, according to the position of the point of impact.

Idea of Robins  
with regard to  
the cause of  
deviations of  
projectiles.

4. It was asserted by Robins,—“That almost all bullets receive a whirling motion by rubbing against the sides of the pieces they are discharged from; and that this whirling motion of the bullet occasions it to strike the air oblique to the track of the bullet, and consequently perpetually deflects it from its course.” Shot cannot be cast with perfectly smooth surfaces; consequently, a certain amount of friction is said to arise between these surfaces and the atmosphere.

The manner in which the ball is deflected, according to Robins, may be thus explained.—As the air in front of the ball will in the above case (Art. 3) be greatly condensed, while almost a vacuum will be formed behind the ball (Art. 4, Lecture VII), a great resistance will be offered by the friction of the air in front, which will not be counterbalanced by a corresponding resistance behind, and therefore the ball will have a tendency to deflect in the opposite direction to that given it by striking the right side of the bore. This is shewn in Fig. 2, Plate 27, the dotted arrow representing the resistance caused by the friction of the air to the rotation, and which not being balanced by a corresponding resistance to the opposite hemisphere will cause the ball to deflect in the direction (*d*).

Robins' experiment before the Royal Society in 1746 (see p. 165 Boxer's Treatise), is very curious, and fully bore out his ideas with regard to the effect that the air has upon balls during their flight. Having fired a bullet from a musket through two screens into a wall, in order to ascertain the direction of its

trajectory, he then bent the end of the barrel to the left, at about three or four inches from the end, and at an angle of  $3^{\circ}$  or  $4^{\circ}$  to the straight portion. When a bullet was now fired, it, as may be supposed, passed through the screens to the left of the track followed by the former bullet, but on the wall it struck considerably to the right of the point of impact of the first. The second bullet fired when the barrel was bent thus, described a doubly curved line, one curve being caused by gravity, and the other by the resistance of the air to the rotation of the bullet; for in passing out of the barrel, the bullet naturally sliding against the right side, a rotation from the left to right was imparted to it, and the air resisting the rotation as before explained, would cause this gradual bearing off to the right.

Experiments  
of Professor  
Magnus.

5. Professor Magnus, of Berlin, made a number of careful experiments some few years ago, to ascertain the causes for the deviations of projectiles, and as they appear to afford the most probable explanations for the different results observed in practice, it is considered necessary to give some account of them here; those relating to spherical projectiles only will be described at present.

The first object was to determine the relative amount of atmospheric pressure exerted on different parts of the projectile, when the latter has imparted to it a motion of translation as well as a motion of rotation. It was assumed that the relative pressures upon the projectile are the same, whether it is made to move with a certain velocity through the air, or whether a current of air is impelled with the same velocity against the projectile.

Observations being more easily made on a cylinder than on a sphere, a brass cylinder (see Fig. 3, Plate 27) about  $1\frac{1}{4}$  inches in diameter and 4 inches high was used to represent the projectile, and it was arranged so that it could be made to rotate rapidly on a concentric or eccentric vertical axis. The current of air was produced by means of a rotating fan, the direction in which it was driven being perpendicular to the axis of the cylinder; the nozzle *AB* which delivered the stream was five inches wide, so that the cylinder might be within the current whatever the position of its axis; the depth of the nozzle was three-quarters of an inch. Two light moveable vanes (*DD*) were placed on each side of the cylinder, so that their pivots were equidistant from the mouth of the blower and from a vertical plane passing through the centre of the current and the axis of the cylinder.

If the cylinder is at rest and the current of air impelled against it, the pressures will manifestly be equal on both sides of the axis, and the vanes are found to place themselves parallel with the current. But when the cylinder is made to rotate from left to right as indicated by the arrow in the circumference of *C*, Fig. 3,

the portion of air in contact with it (dotted arrows round, see Fig. 3) is also made to rotate in the same direction. The cylinder being made to rotate, and the blower being also applied, it is found that the vane on the left side of the cylinder, when the current of air from the blower and the rotating current follow the same direction, approaches the cylinder, but the vane on the other side where the two currents move in opposite directions is found to recede from the cylinder. It would appear from this that on the left side there is a diminished pressure, and on the right side an increased one, compared with the pressures on the cylinder when at rest. In order to obtain the most distinct effects, the velocity of the air produced by rotation must be nearly as high as that of the current of air from the blower.

6. It was shewn by M. F. Savart that if two jets of liquid, flowing with the same velocity from circular orifices of the same diameter, meet each other, when their axes are in the same straight line, the two together move laterally and in a plane perpendicular to the jets. This may be illustrated in the case of gases by the ordinary fish-tail burner, the flame from which is in a plane at right angles to that passing through the two perforations from which the flame issues; thus in Fig. 4, Plate 27, *AB* represents the plane of the flame, and *ab* that passing through the perforations. Also in the experiment with the cylinder, on the right side where the current of air from the blower moves in an opposite direction to the air rotating with the cylinder, when the two currents meet they move laterally, an increased pressure being therefore exerted on the vane forcing it outwards, and on the cylinder; whereas on the opposite side, in consequence of the two currents of air moving together, the pressure is decreased, and the vane approaches the cylinder.

7. In order to prove that the difference of pressure upon the opposite hemispheres of the ball is sufficient to cause it to deviate, Professor Magnus devised the following experiment:—  
 “A light beam of wood, about four feet in length, is suspended from its centre by a thin wire, so as to form a sort of torsion balance; from one end of this beam a brass rod descends carrying a brass ring, within which a light brass cylinder (similar to that described above), turns very freely on an axis, in the same manner as a common terrestrial globe turns within its brazen meridian. At the other end of the beam a counterpoise is adjusted. The blower before cited is placed below the beam, so that it may be made to turn horizontally about a point nearly coincident with the prolongation of the suspending wire, while the mouth is about 2 in. from the cylinder. The plane of the ring being made perpendicular to the direction of the blast, the cylinder is now made to rotate rapidly from right to left, or

*vice versa*, by means of a thread wound round its axis, in the same manner that a humming top is spun. While this is in a state of rotation the blower is put into action. The beam then with the cylinder revolves, and may be made to describe a large portion of a circle, the direction of its orbit depending on the direction which is given to the rotation of the cylinder on its axis."<sup>1</sup>

Application  
of Magnus'  
experiments to  
spherical pro-  
jectiles.

8. Let these principles be applied to the case of ordinary spherical projectiles fired from guns. If a ball leaves the bore rotating on a vertical axis, the fore part of the ball moving from left to right, supposing the observer to be behind the piece, it follows from what has been previously said that there will be a diminished pressure on the right side, and an increased one on the left side of the ball, which will therefore deviate to the right: this is shewn in Fig. 5, Plate 27, in which *AB* represents the direction in which the ball is impelled, *cd* that of the deviation, and the small arrows outside the ball the directions of the two currents of air on both sides. In like manner, if the fore part of the ball turns from above downwards, the increased pressure will be above and the decreased below, and the range would therefore be diminished. In one case alone will there be no deviation from the causes described, and that is when the axis of rotation of the ball is tangential to its trajectory.

It has been already explained, that the velocity of the air rotating with the ball must be nearly as high as that of the opposing current, in order that the pressure on one hemisphere caused by the meeting of the two, may have sufficient power to produce very evident deviations; this will in some measure explain the fact, that the lateral deviation is found in practice to increase in a higher ratio than the distance, for the velocity of translation decreases most probably more rapidly than that of rotation, and therefore the velocities of the two separate currents will become more nearly equal.<sup>2</sup>

Deviations  
of eccentric  
spherical  
projectiles.

9. From the above explanations either of Robins or Magnus, it appears that a ball leaving the bore of a gun rotating on any axis, except one parallel to that of the bore, will deviate according to the direction of the rotation; and they will account for the results of experiments with eccentric projectiles. Should the centre of gravity of a shot not coincide with the centre of the figure, the shot is termed eccentric, and is found to deviate according to the position of the centre of gravity when the ball is placed in the bore of the gun. Should

<sup>1</sup> Journal of U. S. Institution, p. 493.

<sup>2</sup> It appears that if a shot rotates on any axis when leaving the bore of a gun, it will deflect in the same direction, according either to Robins or Magnus; the rotation of the air round the projectile, as explained by the latter, is no doubt caused chiefly by the friction between it and the ball.

the line joining the centre of gravity and the centre of the figure of a projectile be not parallel to the axis of the bore, the charge of powder will act upon a larger surface on one side of the centre of gravity than on the other, so that there will be a rotation from the lightest to the heaviest side. If Fig. 6, Plate 27, represents an eccentric shot, the centre of gravity ( $G$ ) of which is below its centre of figure ( $P$ ), the powder, acting on a larger surface above ( $G$ ) than below, will give it a rotation as indicated by the arrows, and from what has been previously said, its deviation will be to the side upon which the centre of gravity lies. This is the case in practice, for it is found by experiment that if a shot be placed in a gun, so that its centre of gravity is to the right of the vertical plane, passing through the axis of the bore, the shot will deviate towards the right, and *vice versa*; also, if the centre of gravity be upwards the range will be increased, and if downwards diminished. Figs. 6 and 7, Plate 27, will illustrate these remarks.

Trajectory,  
a curve of  
double curva-  
ture.

10. It is found in practice that shot deviate in a curved line, either right or left, the curve rapidly increasing towards the end of the range. This most probably occurs from the velocity of rotation decreasing but slightly, compared to the velocity of translation of the shot as before explained; or, if a strong wind is blowing steadily across the range during the whole time of flight, this deflecting cause being therefore constant, while the velocity of the shot diminishes, the curve will manifestly increase with the range. The trajectory is therefore a curve of double curvature, its projection on either a horizontal or vertical plane being a curved line.

*The object of Rifling, and considerations in connexion with its application.*

Object of  
rifling.

11. By a successful introduction of the rifle system in the construction of ordnance and projectiles, the chief causes of deviation are very greatly diminished. The object of rifling the bore of a piece of ordnance (or of a musket barrel), is to give the projectile a rotatory motion on an axis parallel to that of the bore, or coincident with the "line of fire." By giving this rotation to the shot, the friction or the pressure of the air will be equally distributed round it, thus obviating the chief cause of deflection, and securing greatly increased accuracy.

Manner of  
giving the  
projectile a  
rotatory  
motion.

12. Two different ways of giving the requisite rotatory motion to a projectile suggest themselves.

- (1) By mechanical means inside the bore of the gun.
- (2) By the action of the air upon the projectile itself after it has left the bore.

In order to obtain rotation by the latter, the projectile is provided with wings, spiral grooves, or other contrivances for the air to act upon ; but as none of these have succeeded practically, it will only be necessary to refer briefly to the first method. Two or more grooves are cut spirally down the length of the bore, and the projectile must have projections on its surface to fit into those grooves, or else a portion or all of it must be composed of soft material, so that this latter may by the force of explosion be expanded or compressed (as the case may be) into the grooves, the projectile being therefore constrained to follow their direction while passing through the bore.<sup>1</sup>

Most important considerations, in rifling.

13. The three most important considerations in the application of the "rifle principle" to fire-arms are,

- (1) The form of projectile.
- (2) The grooving of the bore of the piece.
- (3) The charge of powder.

*Elongated Projectiles for rifled pieces.*

Elongated projectiles used with rifled pieces.

14. The rifled muskets first introduced which had two grooves were fired with a belted spherical ball, but the advantages of elongated projectiles over spherical bullets became so manifest that the latter are no longer used with rifled pieces. Elongated projectiles cannot be used with advantage if fired from smooth-bored pieces, for should the pressure of the air act unequally upon them, which always must occur in practice soon after leaving the bore, they turn over in their flight (from the natural tendency of bodies of similar form to rotate round their shortest axes), and are therefore useless ; at short ranges satisfactory results might perhaps be obtained, if the projectile was made to fit the bore without any windage, like many of those for rifled arms. The rotation given to an elongated projectile, round its longer axis, in passing through the bore of a rifled piece, ensures its proceeding in the desired direction with but little deviation.

Elongated projectile proposed by Robins.

15. In 1747, Robins suggested an elongated bullet of an egg-like form<sup>2</sup> :—"For," he says, "if such a bullet hath its shorter axis made to fit the piece, and it be placed in the barrel, with its smaller end downwards, then it will acquire, by the rifles, a rotation round its longer axis ; and its centre of gravity lying nearer to its fore part than its hinder part, its longer axis will be constantly forced by the resistance of the air into the line of its flight ; as we see, that by the same means, arrows

<sup>1</sup> The different systems of rifled guns will be described in Lecture X.

<sup>2</sup> A great objection to this shaped bullet is that there is no certainty of its longer axis coinciding with that of the bore when placed in, the force of the powder not acting therefore through this axis.

constantly lie in the line of their direction, however that line be incurvated." The results of experiments with these bullets of Robins' are thus given by Colonel Beaufoy, in his work called *Scloppetaria*. "At long distances, that is, from 300 to 600 yds. when fired from a gun of  $\frac{1}{8}$  in. bore, they were found much less liable to deviation than at 200 yds. and under, with this peculiarity, that in windy weather, whereas balls are usually driven to leeward of the object, these had a diametrically opposite effect. It was found however, that these balls were subject to such occasional random ranges, as completely baffled the judgment of the shooter to counteract their irregularity." Their deviations to windward no doubt arose, like those of rockets, in consequence of the centre of gravity of the projectile being so far forward, and as such deviations must always be exceedingly variable, they cannot be corrected by the laying of the gun. This objection will apply to all projectiles having their centres of gravity placed in a similar position.

Forms of  
elongated pro-  
jectiles in use.

16. Elongated projectiles were not used (from rifled arms) for the purposes of war till 1846, when excellent results were obtained by the French army in Africa with a cylindro-conical bullet, which had been proposed by M. Delvigne, a French officer. The form of bullet was afterwards modified into a cylindro-ogival bullet, and was an approximation to the form of solid body given by Sir Isaac Newton, in his "*Principia*," which would in passing through a fluid, experience less resistance than a body of equal magnitude and of any other form. This form, proposed by Sir Isaac Newton, is cylindro-conoidal, and he imagined it might be useful in ship building, although it is equally applicable to the theory of projectiles (see Sir H. Douglas, p. 149).

The elongated projectiles now in general use both for rifled small arms and ordnance are of cylindro-conoidal form, modified according to the system of rifling for which they are intended. In Plate 31 the elongated bullets have conoidal points; in Figs. 10 and 11 the difference between the conical and conoidal points may be observed; the former being conical and the latter conoidal. The Armstrong (Fig. 6, Plate 32), the French, and Prussian projectiles (Figs. 13 and 16, Plate 31), are cylindro-conoidal in general form. Flat-headed or cylindrical projectiles are sometimes used for penetrating iron plates, as before mentioned in Art. 50, Lecture VII. Before correct ideas can be formed as to the relative advantages of differently shaped projectiles for rifled arms, it will be necessary to consider how the resistance of the air affects the motion of an elongated projectile. In the following remarks it will be assumed that the centre of gravity of the projectile coincides or is very near to the centre of the figure, for in almost all elongated projectiles



in use this is the case ; the objection to the centre of gravity being far away from the centre of the figure has been already pointed out (Art. 15).

Parallelism of the axis of an elongated projectile when fired with a low velocity.

17. When an elongated projectile is fired from a rifled gun, it leaves the bore rotating rapidly round its longer axis, and if the initial velocity be very low, the projectile experiencing but slight resistance from the atmosphere, the longer axis will remain during the whole time of flight parallel or nearly so to its primary direction, as shewn in Fig. 9, Plate 27. That this is the case may be easily proved by experiment.

Effect of the resistance of the air upon a projectile moving with a high velocity.

18. In explaining the complicated effect produced by the resistance of the air upon an elongated projectile moving with a high velocity, the projectile will be supposed to have what is termed a right-handed rotation ; that is to say, the upper part turns from left to right, with reference to an observer placed behind the gun (as in Fig. 8, Plate 27) ; for, the direction of the grooves of rifled pieces are almost invariably made so as to give such rotation.

After the projectile has left the bore, the resultant of the resistance of the air will act upon a point in front of the centre of gravity and below the longer axis, at all angles of elevation given in practical gunnery. Now the effect produced by this pressure will depend upon the form of the head of the projectile ; therefore, in the first place, the effect upon a conoidal head will be considered, and secondly that upon a flat head.

Cylindro-conoidal projectiles.

19. The effect of a pressure on a rotating projectile may be observed by means of an instrument called a gyroscope, which for this purpose should have a small elongated projectile substituted for the disc used for ordinary experiments, and the projectile must be made with the greatest care, so that its centre of gravity coincides exactly with that of the two rings within which it is placed ; the rings are so arranged that one can turn round a vertical axis and the other round a horizontal axis, the projectile within being therefore free to turn in any direction. A cylindrical portion of metal extends beyond the base of the projectile, in prolongation of its longer axis, round which the string is wound to give the required rotation to the shot. (Fig. 14, Plate 27).

If *ABCDE* (Fig. 12, Plate 27) represent the elongated projectile of the gyroscope, it will be found that a pressure *R*, exerted anywhere between *E* and *D*, will raise the point *D* (when the projectile is not rotating), or in fact, produce a similar effect to an upward pressure exerted at the point *E*. Supposing, however, the projectile to be rotating rapidly in the direction indicated by the arrow (Fig 14, Plate 27), and the pointed end is facing the spectator ; then, if a pressure be exerted at *d* (cor-

responding to  $E$  in Fig. 12), the point of the projectile will not rise (at least perceptibly), but will move laterally in the direction  $c$ , that is to the right with reference to an observer behind the gyroscope; if a pressure be exerted at  $d$ , the point will fall; if at  $a$ , the point will move laterally in the direction  $d$ , or to the left, with reference to an observer behind the gyroscope; lastly, if a pressure acts upon the rotating body at  $c$ , the point will rise. Now should a pressure be exerted on any intermediate part of the circle  $acbd$ , as for instance between  $b$  and  $d$ , then the motion of the point of the projectile will be compounded of the motions caused by respective pressures at  $b$  and  $d$ , that is to say, the point will move laterally to the right (with reference to an observer behind the gyroscope) and droop at the same time.<sup>1</sup> If a strong blast of air be directed upon the fore part of the rotating projectile, the axis of which is slightly inclined to the direction of the blast, as shewn by the dotted lines in Fig. 12, so as to represent the resistance of the air to a projectile moving with a high velocity, the pointed end will first move slowly to the right (towards  $c$ ), effects being afterwards successively produced by the blast similar to those which would be caused by a pressure acting gradually round the circle  $acbd$  (Fig. 14), as already described. If pressure be exerted behind the centre of gravity instead of in front, or on the fore part of a projectile rotating with a left-handed rotation, the above effects will be reversed.

20. To apply these observations practically. If a projectile  $ABCDE$  (Fig. 12), having a right-handed rotation, be fired with a high velocity, the resultant of the air's resistance  $R$ , which would tend to raise the point if the projectile be not rotating, will, it must be evident from what can be observed with the gyroscope, give the point  $D$  a lateral movement to the right, as shewn in Fig. 10.<sup>2</sup> As this lateral movement of the point proceeds, so will the resultant act more and more to the left of the vertical plane, passing through the longer axis of the projectile, and therefore as with the blast before described, or with the pressure acting in Fig. 14 between  $b$  and  $d$ , the point will soon begin to droop. It must however be remembered that a certain amount of time and a considerable resistance, which latter depends upon a sustained velocity, would be required to produce this drooping of the point; that the point falls, so that

<sup>1</sup> The reason for the movement of the point may be familiarly explained thus:—If a rotating cylinder be brought into contact with a resisting surface, the cylinder will roll upon the surface in the direction of the rotation of the upper portion.

<sup>2</sup> It has been sometimes thought that the resistance of the air would lift the hinder part of the projectile, but the resultant of the resistance acts in front of the centre of gravity on a projectile having this centre near that of the figure; and, if the resultant acted behind the centre of gravity it would not lift the hinder part, but produce a contrary lateral movement of the point.

the long axis corresponds with the tangent to the trajectory, is highly probable under certain circumstances, for it is found in practice that the holes made in a target by elongated projectiles fired with high velocities, and at angles up to  $6^\circ$  of elevation or more, are generally spherical, from which it would appear that the projectile struck point foremost, unless the impact on the target itself, the projectile striking rather obliquely, caused the raising up of the posterior end. That the longer axes of projectiles fired under the same circumstances remain during the flight nearly parallel to their primary direction has been inferred from the fact that the lower and hinder part of the projectile has frequently been found cut away by the graze<sup>1</sup> (as at *ab*, Fig. 12), the peculiar form of the graze would also appear to favour this latter idea. If the centre of gravity of a projectile be placed near the point, the longer axis would probably correspond with the tangent to the trajectory throughout the flight, but the Armstrong and other projectiles, which have their centres of gravity very near their centres of figure, almost always strike point first at the angles of elevation necessary for ordinary practice from guns, and their deflections are not so variable as those of projectiles having their centres of gravity near either end.

Deviation of  
cylindro-  
conoidal  
projectiles.

21. It is found in practice that elongated projectiles fired from rifled guns giving a right-handed rotation always deviate to the right of the production of the axis of the bore, and in the few cases tried with guns giving a left-handed rotation the deviation is to the left of the same line; this peculiar deviation of projectiles fired from rifled pieces is called by the French "derivation," and may be thus accounted for. It is most probable that, during the time of flight of a projectile fired with a high velocity under ordinary circumstances, and having a right-handed rotation, the longer axis is inclined to the direction in which the projectile is moving (as in Fig. 10), in consequence of the point turning to the right as before explained; lateral deviation to the right must therefore occur from the resistance of the air acting more upon the left than on the right side.<sup>2</sup> If the projectile has a left-handed rotation, then the point would turn to the left and produce a "derivation" to the left.

Cylindrical  
flat-headed  
projectiles.

22. The effect produced on a cylindrical or flat-headed projectile will now be noticed. A pressure exerted upon the head and below the longer axis, as *R*, Fig. 13, Plate 27, will

<sup>1</sup> The lead, contrary of Armstrong's shells is frequently thus cut away; not the iron underneath, which offers so much resistance.

<sup>2</sup> It was found by experiment carried on at Berlin, that in all the rounds fired, the point of the projectile at the instant of touching the ground had a deviation to the right, as shewn in Fig. 11, Plate 27. (See Magnus on the Deviation of Projectiles. Occasional papers of R. A. Institution, Vol. I, page 444.)

when the projectile is not rotating cause the head to droop, or will produce an effect similar to a downward pressure acting at *C*, just the opposite to what was before observed with a conoidal pointed projectile. It would therefore appear that the fore part of a flat-headed projectile fired with a right-handed rotation would in consequence of the resistance of the air, not turn to the right but to the left, and this is found to be the case if a blast of air is directed upon a projectile of this form in a gyroscope, the axis of the projectile being slightly inclined upwards as before. It has been asserted that flat-headed projectiles,<sup>1</sup> fired with a right-handed rotation, deflect to the left, and this could only arise from the turning of the point to the left, but there has not been sufficient experimental practice to decide whether such would invariably be the case.

Principles  
deduced from  
the above  
remarks.

23. It might be imagined from the above remarks, that, as a conoidal point is turned by the resistance of the air to the right with a right-handed rotation, and a flat-head to the left, a form of projectile might be adopted, which should deflect neither way; as however there would be very great difficulty in practically constructing projectiles with the necessary accuracy, and that errors in form would produce deflections, which could not be foreseen or allowed for, it would appear better that the form of projectile should be such that a small and constant deflection to one side may be relied on.

The method of rifling should be such, that the projectile on leaving the bore may not be deformed by large projections on its exterior surface, upon which the air might act unequally, and therefore cause uncertain deviations. It would also appear advisable that the centre of gravity of the projectile should be near that of the figure. It is most important that the axis of the projectile should correspond with that of the bore of the piece from which it is fired, for otherwise the axis of rotation will be variable and the deflection of the projectile uncertain, depending upon the position of its axis on leaving the bore.

The advantage as regards range gained by increasing the length and decreasing the diameter of a projectile have been already referred to in Art. 27, Lecture VII; as however the length of a projectile is increased, so must the velocity of rotation be more rapid, in order to counteract the greater tendency to turn over in flight. Range is said to be increased to some extent by tapering off the projectile behind (see Fig. 13, Plate 31), or by making both the ends conoidal in form.

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<sup>1</sup> Projectiles cylindrical or nearly so in form are here referred to, and not those with flattened conoidal points, for in certain cases the resultant of the resistance of the air might fall upon the conoidal part.

Cannelures  
and their  
object.

24. In order to overcome the "derivation," and to keep the axis of the projectile tangential during the whole time of flight to the trajectory, M. Tamisier proposed to place several circular grooves (cannelures) in the cylindrical part, so that the resistance of the air acting upon these grooves behind the centre of gravity of the bullet, should tend to bring down its point upon the curve of the trajectory; if the point falls below this curve, the resistance then acting above would tend to raise the point (Fig. 3, Plate 26). These grooves have not however been found to overcome the "derivation" of a bullet, although perhaps to decrease it; for by increasing the pressure behind the centre of gravity the "derivation" would not most probably be done away with, the point of the projectile as before explained moving in the opposite direction in consequence of this pressure, and causing "derivation" on the contrary side.

Range of  
elongated  
projectiles at  
certain low  
elevations  
greater in air  
than in vacuo.

25. It was asserted by Sir W. Armstrong and others, that at certain low elevations the range of an elongated projectile is greater in the atmosphere than in vacuo, and the following is the explanation given by the former, of this apparent paradox. "In a vacuum the trajectory would be the same whether the projectile were elongated or spherical, so long as the angle of elevation, and the initial velocity were constant; but the presence of a resisting atmosphere makes this remarkable difference, that while it greatly shortens the range of the round shot, it actually prolongs that of the elongated projectile, provided the angle of elevation does not exceed a certain limit, which in my experiments, I have found to be about 6°. This appears at first very paradoxical, but it may be easily explained. The elongated shot if properly formed, and having a sufficient rotation, retains the same inclination to the horizontal plane throughout its flight, and consequently acquires a continually increasing obliquity to the curve of its flight. Now the effect of this obliquity is, that the projectile is in a measure sustained upon the air, just as a kite is supported by the current of air meeting the inclined surface, and the result is that its descent is retarded so that it has time to reach to a greater distance."

When the above explanation was given the initial velocity of the projectile fired from the 12-pr. Armstrong gun was supposed to be under 1100 ft. per second; since then, however, experiments have been made from which it was found that the initial velocity is as high as 1191 ft. and it will be seen below that with this latter velocity the above theory will not hold good to 2°.

	1°.	2°.
Range in vacuo. . . . .	512	1023
„ air <sup>1</sup> . . . . .	620	966

<sup>1</sup> The ranges here given are not those obtained by the grazes of the projectile, but at imaginary points of the same distance above the ground as the muzzle of the gun.

The greater range at  $1^{\circ}$  may be accounted for by the muzzle of the piece being thrown up from the action of the recoil, before the projectile has left the bore.

*Number, Form, and Inclination of the Grooves.*

Number and depth of grooves.

26. It is absolutely necessary to have two grooves, a single one would give a wrong direction; some rifles are made with as many as forty grooves, or even more. The width of the grooves will of course depend upon the number. Grooves must not be too deep, or projections will be formed on the bullet, upon which the resistance of the atmosphere would act injuriously; deep grooving renders the bore difficult to clean and subject to fouling, besides weakening the metal of the gun. If the grooves are shallow and numerous, instead of deep and few in number, less resistance will be offered to a projectile which expands or is forced into them by the explosion of the charge; also the cylindrical part of the bullet will issue from the bore less deformed in shape, and therefore less liable to injurious effect from the atmosphere, it will preserve its velocity of rotation longer, and in all probability its deflection will be reduced.

Inclination of the grooves.

27. The inclination of the grooves is a point of very considerable importance, and very different opinions are held with regard to the velocity of rotation required for projectiles of different lengths and forms. Should the projectile rotate slowly during any part of its flight, the motion of the longer axis will become very irregular, and the accuracy of fire will consequently be greatly impaired or even lost. A very high velocity of rotation is objectionable for the following reasons;—that the strain upon the metal of the gun will be very great, for the charge must be comparatively large, and the grooves will require a sharp turn, much resistance being thereby caused to the motion of the projectile; that the projectile after grazing will deflect considerably; and that should the projectile be a shrapnel or segment shell, the pieces would spread laterally to too great a distance to be effective.

Velocity of rotation of a shot dependent upon inclination of grooves and initial velocity.

28. The velocity of rotation of a shot will depend upon its initial velocity, and the inclination of the grooves or "twist" as it is technically called. In order to find the velocity of rotation of a projectile on leaving the bore, divide the "initial velocity" (in feet) by the number of feet in which one complete turn or revolution is made by the shot; thus in Sir W. Armstrong's 12-pr. the turn is 1 in 38 calibres (1 calibre=3 inches) or 9.5 feet, and as the initial velocity is 1191 feet per second.

The velocity of rotation will be  $= \frac{1191}{9.5} = 125.3$  revolutions per sec.

In a French report on experiments with long bullets it is stated that "in proportion as the ball increases in length, and

therefore in weight, grooves with greater inclinations but small "charges should be used"; "with small charges of powder the twist of the grooves may be very great; with large charges the inclination should be very slight." These remarks have reference to leaden bullets which are liable to "strip," as it is technically called, or to be forced across the grooves, not therefore receiving the requisite rotation.

The velocity of rotation must be increased with the length of the projectile, as before stated, but it does not seem desirable to decrease the charge, for with equal charges the velocity of the longer and therefore heavier projectile would be lower than that of the shorter one; there would appear to be little use in increasing the inclination of the grooves unless the velocity is at the same time maintained, if not increased.

**Gaining twist.** 29. Some rifles are made with what is called a "gaining twist," the grooves having but a slight inclination at the breech, but increasing regularly towards the muzzle; this was the case in the Lancaster rifled ordnance. The objection to such an arrangement of the grooves is, that a continually increasing resistance is offered to the ball's progress, while at the same time the velocity of the ball is also increasing; there will consequently be a great tendency to strip when the bullet is made of soft material such as lead, but if of hard material, as in the case of the projectiles of wrought-iron for the Lancaster gun, there will be danger of fracture, either to the gun or projectile.

#### *The Charge.*

**Charge.** 30. The form and weight of the projectile being determined, as well as the inclination of the grooves, the charge can be so arranged as to give the necessary initial velocity, and velocity of rotation; or if the nature of projectile and charge be fixed, the inclination of the grooves must be such as will give the required results. The most important consideration is the weight and form of projectile, the inclination of the grooves, the charge, weight of metal in the gun, &c. are regulated almost entirely by it. The charges used with rifled pieces are much less than those with which smooth-bored guns are fired, for there is little or no escape of gas, and as an elongated projectile fired from a rifled gun is not set in motion so quickly as a ball from a smooth-bored piece, more time is allowed for the combustion of the powder, the greater part of which is most probably converted into gas in many rifled guns before the projectile has sensibly moved; it is found in practice that with comparatively low initial velocities, elongated projectiles maintain their velocities and attain very long ranges, but in certain cases, as for instance when penetration is required, higher velocities would doubtless be advantageous. At

present however few guns would be able to stand larger charges than those generally employed, the strain upon a rifled gun being comparatively so much greater than that upon a smooth-bored piece. The charges for different rifled ordnance are as follows :—

For the Whitworth gun  $\frac{1}{8}$  the weight of the projectile.

„	Armstrong	„	$\frac{1}{8}$	do.
„	French	„	$\frac{1}{8}$	do.
„	Prussian	„	$\frac{1}{10}$	do.

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## APPLICATION OF GUNNERY.

### *Application of Gunnery.*

1. THE practice of gunnery from ordnance may be divided into horizontal and vertical fire.<sup>1</sup> For horizontal fire, guns and howitzers are employed, the charges of gunpowder being generally fixed, and the ranges of the projectiles regulated, by the elevation of the axis of the piece; this elevation, for any purpose, rarely exceeds  $10^{\circ}$ . Mortars are used for vertical fire, these pieces being usually fixed at a constant elevation of  $45^{\circ}$ , and the ranges regulated by increase or decrease of the charge. Howitzers and guns may, under extraordinary circumstances, be employed for vertical fire.

### *Horizontal Fire.*

Laying guns  
and howitzers.

2. In order that a projectile fired from a gun or howitzer may strike a required object, it is necessary to, what is technically called, "lay" the gun; this term includes two operations, viz. first (with smooth-bored ordnance) to bring the axis of the piece into the same vertical plane with the object; and, secondly, unless the distance be within "point blank range" to give the axis a certain elevation above the plane, passing through the object and the axis of the piece.

To obtain the  
correct line.

3. As the axis of the gun is not visible, it is necessary to make use of notches or "sights" on the exterior surface, to determine practically the position of the axis. The "line of metal" is a visual line, joining the notches cut on the highest points of the base ring and swell of the muzzle when the trunnions are perfectly horizontal. This line being in the same vertical plane as the axis, it is only requisite to bring the two notches and the object into the same line to insure the piece being properly pointed; in allowing for wind or other deflecting causes, these notches must be brought into line with some point right or left (as the case may require) of the object.

4. Should the carriage, however, stand on uneven ground, which may frequently happen in the field, one trunnion will be higher than the other, in which case, the external form of the gun being conical, the above notches will not be in the same vertical plane with the axis, but in a plane inclined to it, and the shot will be thrown to the side of the lowest trunnion.

<sup>1</sup> These terms express the respective directions in which projectiles take effect; for instance, in either direct or ricochet fire, when it is required to strike guns, men, or works, the less curved (or more nearly horizontal) the trajectory of a projectile, the greater will be the effect produced; whereas, in mortar firing vertical penetration is wanted, and consequently the shell should descend in a direction as nearly vertical as can be obtained.

This is shewn in Fig. 3, Plate 25, where the piece is directed by the notches at *A* and *C*, on the object *B*. The shot will proceed in the line *DE* to the right of the object *B*, and at a long range this deflection *BE* would be considerable. In Fig. 4, Plate 25, where there is a dispart patch, making *FC=DA*, there will be no appreciable deflection from the trunnions not being horizontal, the lines of sight and fire being parallel at a distance of merely an inch or two.

5. With Sir W. Armstrong's rifled guns a horizontal slide is attached to the elevating tangent scale, by means of which allowance can be made for "derivation" or wind. In Fig. 4, Plate 26, let *AB* represent the gun, *DC* its "derivation" for the range *BC*; if *op* be the horizontal slide *AO* is the allowance upon it for *DC*, as the triangles *AoB* and *CDB* may be considered for all practical purposes similar. Therefore if the points *o*, *B*, and *C* be brought into line, the shot will gradually deflect from the line *BD* until it finally strikes the object at *C*.

Consequently, instead of bringing the axis of the gun into the same vertical plane with the object, it is brought into the same vertical plane with an imaginary point at a lateral distance from the object corresponding with its known deflection at the given range. In allowing for wind without a horizontal slide the piece is obliged actually to be laid upon a point right or left of the object, the sights not being therefore in line with object, and by this rough method considerable errors are likely to arise in range as well as in deflection; with smooth-bored ordnance there is no such thing as constant deflection, yet a horizontal slide would be of great use in allowing for wind, &c.

To obtain the required elevation.

6. The charge of a gun or howitzer being fixed, and the initial velocity therefore being constant, the distance to which the shot will range depends upon the inclination of the axis of the piece to the plane upon which the gun (on its carriage) is resting. From what has been previously said, it is evident that, in firing at a given object, the axis of the gun must be directed upon a point at a sufficient vertical distance above the object, to allow for the action of gravity, which causes the ball continually to descend after leaving the bore of the piece.

The elevation of the axis of a gun is generally regulated by means of tangent scales, which are graduated in such a manner, that the divisions correspond with the various ranges required from the gun. Before explaining the principle upon which the tangent scale is graduated it will be desirable to define the terms "point blank," "point blank range," and the "line of metal elevation."

Point blank.

7. A gun is said to be laid point blank when the production of its axis will pass through the object aimed at; a gun may

therefore be "point blank," with reference to an object, and yet have several degrees of elevation or depression with regard to the horizon.

Point blank range.

8. The "point blank range" of a gun is represented in Fig. 1, Plate 28. The gun on its carriage is fired on a horizontal plane, the axis of the gun being laid parallel to the plane. The distance to which the shot will range in this case, before it grazes the plane at *D* will evidently depend, first, upon *AC* the height of the muzzle of the gun above the plane; and, secondly, on the initial velocity of the shot which varies with the charge. The resistance of the air, of course, depends upon the latter. We therefore obtain the following definition, viz.

"The point blank range<sup>1</sup> of a gun is the range obtained at the first graze of the shot, when the piece placed on its carriage is fired, with the service charge, on a horizontal plane with no elevation: that is to say, when the axis of the gun is parallel to the plane."

Line of metal elevation.

9. If a gun be laid upon an object by means of the line of metal (there being no dispart patch), it is evident, from the conical form of the gun, that the prolongation of the axis will pass over the object aimed at. (Fig. 2, Plate 28). The elevation thus obtained is called the "line of metal elevation," and varies in different guns.

In light field guns, it is....	1°
Medium do. ....	1½°
Ordinary iron guns .....	1½°
Col. Dundas' 56-pr. ....	2°
Monk's guns .....	2½°

Line of fire.

10. Figs. 3, 4 and 5, Plate 28, will explain the principle upon which a gun is elevated. In order that a shot may strike the object at *E*, the axis of the piece *GH* must be directed upon a point *D*, which is at a vertical distance above *E*, corresponding to the time of flight required for the range, and at the end of which time the shot will be brought to the earth by the force of gravity; the production of the axis of the piece which passes through *D* is termed the "line of fire."

Line of sight.

11. The elevation of the axis is accomplished by means of a tangent scale, the top of which *A*, the sight *C*, and the object *E*,

<sup>1</sup> The French definitions of point blank and point blank range are as follows. "The second point at which the trajectory cuts the line of metal is called the 'point blank' (*but en blanc*), and its distance from the piece the 'point blank range;' from which it will be seen that their 'point blank range' corresponds very nearly to our 'line of metal elevation.'"

being brought into the same line, called the "line of sight," will give the axis the required angle of elevation  $a$ .

**Trajectory.** 12. The trajectory (or path which the centre of gravity of the shot describes in its flight)  $HME$  cuts the line of sight in two points; first at  $O$ , a short distance from the muzzle, and again at  $E$  the object, should the elevation be correct.

**Angle of elevation.** 13. The "angle of elevation" of a gun may be defined as the angle which the "line of fire" makes with the "line of sight."

**Method of calculating any required length of tangent scale.** 14. In order to calculate the correct length of tangent scale for any required elevation  $a$ .

From the similar triangles  $ODE$  and  $ABC$ ,

$$AB :: BC :: DE :: OE,<sup>1</sup>$$

and  $AB$  will be the length of tangent scale required, if the gun has a dispart patch, as is Fig. 4, Plate 28.

$$\text{and } AB = BC \times \tan a \\ = \text{length between sights} \times \tan a \dots\dots\dots (1)$$

If, however, there be no dispart patch, as in Figs. 3 and 5, the length of tangent scale will be equal to  $AF$ ,

$$\text{and } AF = BC \times \tan a - BF, \\ = \text{length between sights} \times \tan a - \text{dispart} \dots\dots (2)$$

These formulæ are not strictly correct, owing to the tangent scale not being perpendicular to the axis of the piece, except in field guns.

15. Should very great accuracy be wanted, the requisite formulæ may be found as follows (Fig. 1, Plate 29):—

Let  $a$  = angle of inclination of the tangent slide;  
 $b$  = given angle of elevation;  
 $c$  = angle of dispart;  
 $r$  = short radius;  
 $R$  = long radius or actual distance from tangent sight to muzzle sight;  
 $x$  = length of tangent scale required.

Up to the "clearance angle,"<sup>2</sup> that is, when  $b$  does not exceed the angle  $AEB$ ,

$$x = r \frac{\sin b}{\sin (90 + a - b)} \dots\dots\dots (3)$$

When the angle of elevation is greater than the "clearance angle," that is, when  $b$  is greater than  $AEB$ .

$$\text{Then } x = R \frac{\sin DFB}{\sin BDF} \\ = R \frac{\sin (b - c)}{\sin (90 + a - b + c)} \dots\dots\dots (4)$$

<sup>1</sup>  $OE$  may be considered =  $CE$ , as the distance  $CO$ , is so very small compared with  $CE$ , the range.

<sup>2</sup> So called from the fact that, if the angle of elevation exceeds it, the middle sight will fall below the muzzle, and the muzzle notch must therefore be taken as the second sight. Fig. 5, Plate 28, is an instance of this.

Peculiarity of  
Sir W. Arm-  
strong's tan-  
gent scale.

16. In the tangent scales hitherto used there is a notch cut in the top, through which the observer looks, bringing the notch in the muzzle or the top of the dispart sight into line with the object; errors are liable to arise from different parts of the notch (as top, bottom, or centre), being taken as a point of sight according to the idea of the observer. In order to secure greater accuracy in laying, Sir W. Armstrong's tangent scale, instead of the notch, has two slits<sup>1</sup> cutting each other at right angles, the intersection being therefore taken as the point of sight; there are also two verniers attached to this scale, one to the horizontal and the other to the vertical slide, so as to give minute alterations in deflection or range; these verniers would be of no practical utility with smooth-bored ordnance (Art 1, Lect. VIII.).

17. The various kinds of tangent scales and sights used in the service, as also the practical method of graduating the former, are described in the manuscript notes on the Proof Department.

18. Besides the tangent scale, there are other means of giving elevation to a gun, viz. by the quarter-sights, by the spirit level quadrant, or by the gunner's quadrant.

Quarter-sights.

19. The elevation as far as  $3^{\circ}$  is cut on the sides of the base ring in bronze field guns and some iron guns, beginning from a notch, which, with another cut in the side of the swell of the muzzle, gives a line of sight parallel to the axis, but a little above it, so as to clear the capsquares of the trunnions.

Spirit-level  
quadrant.

20. In order to give elevation by the spirit level quadrant, the long limb must be inserted into the bore, the spirit level attached to the graduated arc being set to the required angle, and the piece elevated until the spirit level becomes horizontal, which will appear by the bubble resting in the centre of the glass tube (Fig. 2, Plate 29).

Gunner's  
quadrant.

21. With the gunner's quadrant, the muzzle of the gun must be raised until the plumb-line cuts the required angle on the graduated arc (Fig. 3, Plate 29).

22. These instruments only give the elevation above the horizon, but by laying the gun point blank at the object, and determining its elevation above the horizon, the required elevation may afterwards be given. Angles of depression may be taken by reversing the position of the quadrant, and placing it against the face of the piece.

Tables of  
practice.

23. In order to secure good practice, it is essential to have accurate tables of the ranges of the different natures of ordnance,

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<sup>1</sup> This arrangement of slits is only used in the tangent scales for land service, the Royal Navy preferring the old form of notch.

with their corresponding angles of elevation, charges, &c. It is with great difficulty that tables are constructed, even with the aid of the most careful experiments, owing to the very different ranges and deflections obtained in firing projectiles even from the same gun with similar charges and elevations. With good rifled ordnance this difficulty would, no doubt, be greatly decreased; and, for practical purposes, almost entirely overcome at moderate elevations and ranges.

Tables of practice for all ordnance in the service, will be found in the "*Hand Book, for Field Service*," published at the Royal Artillery Institution. The following Tables include the ranges of projectiles from smooth-bored ordnance most generally used in the service.

TABLE A.  
RANGES OF PROJECTILES FROM IRON ORDNANCE.

Nature.	Weight.		Elevation.								Remarks.
			P.B.	1°	2°	3°	4°	5°	6°	8°	
				yds.	yds.	yds.	yds.	yds.	yds.	yds.	
68-pr.	cwt.	lb.	370	900	1170	1660	1860	2140	2400	2740	Solid shot.
			s.	s.	s.	s.	s.	s.	s.	s.	
			—	2·25	3·25	4·25	5·25	6·25	7·75	9·75	
...	95	16	320	700	1070	1410	1710	1930	2140	2540	
			s.	s.	s.	s.	s.	s.	s.	s.	
			—	2·	3·	4·25	5·5	6·5	7·5	9·	
32-pr.	58	10	400	820	1200	1520	1810	2050	2250	2610	
...	56		370	779	1160	1460	1690	1910	2110	2460	
...	50		346	747	1173	1435	1698	1900	2127	2453	
			s.	s.	s.	s.	s.	s.	s.	s.	
			—	2·	3·	4·	5·25	6·25	7·25	8·75	
24-pr.	50	8	360	750	1120	1440	1630	1840	1950	2230	
18-pr.	38	6	350	690	990	1270	1500	1710	1890	2130	Hollow shot.
10-pr.	86	12	315	635	935	1205	1450	1665	1825	2095	
			s.	s.	s.	s.	s.	s.	s.	s.	
			—	2·2	3·4	4·2	5·	6·4	7·	8·7	Common shell [Naval]
8-in.	65	10	320	660	960	1250	1500	1720	1910	2220	
			s.	s.	s.	s.	s.	s.	s.	s.	
			—	2·	3·	4·5	5·2	6·2	7·2	9·2	Hollow shot.
...	52	8	290	530	820	1080	1340	1550	1860	2080	

(s) stands for seconds, and refers to time of flight.  
With common shells a little less elevation is required than for solid shot at short ranges, but at long ranges about the same, at very long ranges more.

TABLE B.  
RANGES OF SHOT AND SHELL FROM FIELD PIECES.

Nature.	Weight.		Elevation.							Remarks.
			P. B.	1°	2°	3°	4°	5°	6°	
12-pr. gun	cwt.	lbs.	300	700	1000	1200	1400	1600	1800	Solid shot
9-pr. "	13½	2½	300	680	960	1190	1400	1590	1750	
6-pr. "	6	1½	200	620	890	1100	1280	1450	1600	
32-pr. how.	17½	3	300	500	700	900	1100	1300	1400	Com. shell
				·2	·4	·6	·7	·9	1·1	
24-pr. "	12½	2½	270	520	760	960	1160	1350	1520	
12-pr. "	6½	1½	200	420	630	800	970	1135	1290	
				·3	·5	·7	·9	·11	·13	

The decimals under the ranges of common shell refer to the length of fuse composition required.

TABLE C.  
RANGES OF CASE SHOT FROM FIELD PIECES.

Nature.	Elevation.		
	P. B.	1°	2°
	yds.	yds.	yds.
12-pr. gun .....	200	300	400
9-pr. " .....	150	250	350
6-pr. " .....	100	200	300
32-pr. howitzer	200	300	400
24-pr. " .....	150	250	350
12-pr. " .....	100	200	300

The following Tables are compiled from the results of practice, carried on in Woolwich Marshes by the Cadets of the Royal Military Academy, during the years 1857, 58, 59.

TABLE D.  
ROUND SHOT.

Nature.	Weight.	Charge.	Range in yards.					Remarks.
			1000	1100	1200	1300	1400	
10-inch gun	86-cwt.	12	deg. 2½	deg. 2½	deg. 3	deg. 3½	deg. 4	Hollow.
8-inch gun	66-cwt.	10	2½	2½	2½	3½	3½	
32-pr. gun	56-cwt.	10	1½	3	2½	2½	3	Solid.
do.	do.	7½	2	2½	2½	2½	3½	Hot.

TABLE E.  
COMMON SHELL.

Nature.	Weight.	Charge.	Range in yards.					
			900	1000	1100	1200	1300	1400
10-inch gun	86-cwt.	12	° fu. 1½ .5	° fu. 2½ .6	° fu. 2½ .7	° fu. 3 .8	° fu. 3½ .8	° fu. 3½ .9
8-inch gun	66-cwt.	10	1½ .4	2½ .5	2½ .6	2½ .7	3½ .8	3½ .9
32-pr. gun	56-cwt.	10	1½ .4	1½ .5	1½ .5	2 .6	2½ .7	3 .8

TABLE F.  
DIAPHRAGM SHRAPNEL SHELL.

Nature.	Weight.	Charge.	Range in yards.				
			1000	1100	1200	1300	1400
8-in.....	65-cwt. ...	lbs. 8	° fuze 3 .5	° fuze 3½ .6	° fuze 4 .7	° fuze 4½ .8	° fuze 5½ .9
32-pr. ....	56-cwt. ...	10	2 .4	2½ .5	2½ .6	3 .7	3½ .8

Elevation on inclined planes.

24. Should it be required to “lay” a gun upon an object situated on an ascending or descending plane, and if the inclination of the plane to the horizon be but slight, little, or no alteration in the elevation, from that used for the same range on a horizontal plane, will be necessary.

If, however, the difference in level between the gun and object be considerable, a greater or less amount of elevation will be

requisite, according as the object is above or below the gun ; this is evident, for in the case of firing upwards gravity will act as a retarding force, while in firing downwards, it will act as an accelerating force.

Rules for the elevation of field pieces.

25. The following general rules for the elevation of ordinary smooth-bored field guns may be of use in practice, and will be found tolerably accurate :—

12 and 9-pr. guns.

The medium 12 and 9-pr. guns (bronze), with their service charges without any elevation, or at point blank range, project their shot 800 yds. before they graze the earth ; every additional  $\frac{1}{4}^{\circ}$  up to  $1^{\circ}$  increases the range 100 yds. ; every additional  $\frac{1}{4}^{\circ}$  from  $1^{\circ}$  to  $2^{\circ}$  increases the range 75 yds. ; from  $2^{\circ}$  to  $3^{\circ}$  every  $\frac{1}{4}^{\circ}$  increases the range 50 yds.

Light 6-pr. and heavy 8-pr. guns.

The light 6-pr. and heavy 8-pr. with service charges, have a point blank range of 200 yds. ; every additional  $\frac{1}{4}^{\circ}$  as far as  $1^{\circ}$  increases the range 100 yds. ; after which, each  $\frac{1}{4}^{\circ}$  up to  $3^{\circ}$  increases it 50 yds. The point blank range of the 24-pr. howitzer is 250 yds., and that of the 12-pr. howitzer 200 yds. ; every additional  $\frac{1}{4}^{\circ}$  for both increases the range 50 yds.

24 and 12-pr. howitzers.

Armstrong guns.

The practical rules given in the “*Manual of Artillery Exercises*” for the Armstrong guns are

Up to 500 yds., 1 minute of elevation may be assumed to give 10 yds. range.

From 500 to 1000 yds., 1 minute of elevation gives 7 yds. in range.

From 1000 to 3000 yds., 1 minute gives 6 yds. ; at distances above 3000 yds., 1 minute gives 5 yds.

Each minute of deflection on the sight gives a difference of an inch in every 100 yds. range.

The following Table, deduced from the results of practice at Shoeburyness, may be found useful until complete Tables are officially promulgated.

TABLE G.  
RANGES OF ARMSTRONG PROJECTILES.

Nature of Gun.	Projectile.	Weight of Projectile.	Charge.	Elevation.											
				PB.	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	
6-pr. ....	{ Segment shell plugged do }	lb. oz. 5 13	lb. oz. 0 12	263	579	885	1167	1456	1683	1958	2182	...	...	...	
12-pr. ....	{ do }	11 8	1 8	...	680	1015	1335	1655	1956	2218	2505	2757	2974	3226	
25-pr. ....	{ Solid shot }	25 0	3 2	258	568	877	1184	1682	2010	2236	2538			3146	
40-pr. ....	{ do }	40 0	5 0	360	700	1040	1373	1698	2015	2321	2614	2890	3160	3400	

Time of flight of shells.

26. When shells are fired, it is necessary to know the time of flight, in order that the correct length of fuze composition may be regulated accordingly. Fuze composition is made to burn at the rate of 1 in. in 5 seconds, so that if the time of flight



be ascertained in seconds, and multiplied by .2 in., the required length of fuze is obtained.<sup>1</sup> Various instruments have been devised for the purpose of registering the times of flight of projectiles fired from ordnance; should no other means be at hand, this may be done roughly by means of a watch having a seconds' hand, the times of flight of several being compared, and the mean taken.

27. The times of flight for spherical projectiles fired at low angles may be roughly calculated as follows, and the results will be found sufficiently accurate for all practical purposes,<sup>2</sup> (Fig. 1, Plate 30).

$$\begin{aligned} \text{Let } BC \text{ or } R &= \text{range (in feet),} \\ DC &= \text{the height of the point } D, \text{ upon which the axis} \\ &\quad \text{of the gun is directed,} \\ a &= \text{angle of elevation,} \\ DC &= BC \tan a, \\ \text{and } DC &= \frac{1}{2}gt^2; \\ \therefore R \tan a &= \frac{1}{2}gt^2. \\ t &= \frac{1}{g} \sqrt{R (\text{in ft.}) \tan a.} \end{aligned}$$

EXAMPLE. A common shell is fired from a 32-pr. iron gun at an object 1400 yds. distant, and for this range 3° of elevation is required; find the time of flight, and length of fuze;

$$\begin{aligned} t &= \frac{1}{g} \sqrt{4200 \times .052} = 3.6, \\ \text{and length of fuze} &= 3.6 \times .2 = .72. \end{aligned}$$

At practice in the marshes, .7 or .8 will be found to be the best length of fuze for this range.

#### *Different kinds of Horizontal Fire.*

28. The various kinds of horizontal fire may be classed as follows:—direct, oblique or cross, reverse, enfilade, ricochet, and curved.

The three first of these terms convey their own meaning; it will only therefore be necessary to explain the others.

In all horizontal firing except in ricochet or curved fire, full service charges are used, as it is desirable to have a high initial velocity, in order that the trajectory of the shot or shell may be as nearly horizontal as possible, the chance of striking an uncovered object being then the greatest.

**Enfilade.**

29. When a battery is placed perpendicularly to a line of troops or works, the shot from the guns raking the line, the fire is then called "enfilade," the guns being fired with full service charges.

**Ricochet.**

30. Ricochet fire consists in placing a battery at right angles

<sup>1</sup> Many fuses are not filled with ordinary fuse composition, but the times of burning are always shewn upon a graduated scale outside the fuse.

<sup>2</sup> The formula used, it will be observed, is that given as (3) in Art. 2, Lecture VII., for the downward velocity of a ball fired at a low angle is but slightly affected by the resistance of the air.

to the line of troops or works aimed at, as in enfilade, but the shot having to clear a parapet which covers them, it is necessary to fire with a reduced charge and greater elevation, so as to give the shot a low velocity and a high curve, in order that it may be brought down immediately after clearing the crest of the parapet, and then by rebounding along the face of the work, dismount the guns, or rake the line of troops under cover, as the case may be.<sup>1</sup>

The velocities being low, it is necessary to give the axis of the piece a considerable elevation, viz. from  $6^{\circ}$  to  $9^{\circ}$  above the crest of the parapet, in order to compensate for the action of gravity upon the shot while passing from the gun to the object. No greater elevation than is absolutely necessary should however be given to the gun, as the shot would either rebound at too high an angle to be effective, or it would penetrate into the ground; whilst the smaller the angle at which the shot reaches the ground, the more horizontal will be its subsequent course, and the greater the velocity it will retain, both of which are essential points in this species of firing. Should the range be unknown, a good plan to be adopted is, to commence firing short of the parapet, and gradually increase the elevation until the shot strikes as near the crest of the parapet as possible; the least increase of elevation will then attain the object (Fig. 2, Plate 30).

The rebounding of shot moving with low velocities produces but trifling effect compared to the devastation caused by the explosions of shells full of powder, and the latter projectiles would generally now be employed against a work, which would formerly have been ricocheted with shot. Shot fired so as to ricochet will rarely dismount heavy ordnance,<sup>1</sup> and they will often pass through or lodge in a carriage without rendering it unserviceable; also but little ground is covered by the shot before and after the graze. Large shells falling close to a gun and then bursting will generally render the platform or carriage unserviceable, and should one explode underneath a gun, the piece may be dismounted. Shells produce a much greater effect than shot upon the traverses and parapets as well as upon men, and if the fuze is bored long a shell may ricochet and then burst, but the rebounding will sometimes extinguish the fuze. Should, however, shells be fired so as to clear the covering parapet, and fall into the battery at different distances from it, the fuzes being regulated so that the shells may burst on grazing, as great effect will most

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<sup>1</sup> Ricochet fire has been in use since 1572, when it was employed at the siege of Haarlem. It was reduced to method and rules made for its accomplishment, in 1688, by Vauban; but it only arrived at perfection at the siege of Ath, in 1697. The introduction of this kind of fire gave a great superiority to the attack over the defence of fortresses. The above definition of ricochet fire (in Art. 30) thus laid down and understood for more than two centuries, has not been altered, but the modification rendered necessary by the substitution of shell for shot fire is pointed out.

<sup>2</sup> Hollow shot constantly break in pieces on striking a gun.

probably be produced as by firing in any other way ; such a fire could not be properly termed ricochet, but would be similar to what is termed in Art. 34, "curved fire."

Position of a ricochet battery, and nature of ordnance best adapted for ricochet fire.

31. A ricochet battery should be placed so that one gun may be directly on the prolongation of the face enfiladed, and the other guns within this one. The ordnance most suitable for the modified ricochet fire of the present day are the 8-inch guns of 52 or 50 cwt., but any rifled gun throwing an elongated projectile, which is capable of holding a large bursting charge might also be used to drop shells into the battery so as to burst on grazing ; the path of an elongated projectile is so eccentric after grazing as to render it unfit for ricochet fire strictly speaking, but as before observed, more effect would probably be obtained by the bursting of any shell in grazing than by allowing it to rebound first.

Best ranges for ricochet fire.

32. It was found by experiment in ricochet firing, carried on at Woolwich in 1821, that at a range of 400 yds. with a charge of powder  $\frac{1}{3}$  the weight of the shot about two-thirds of the number of rounds took effect. At 600 yds. with a charge of from  $\frac{1}{3}$  to  $\frac{1}{2}$  the weight of the ball, about one-half to one-third took effect. At 800 yds. with a charge of from  $\frac{1}{4}$  to  $\frac{1}{2}$  not more than from one-third to two-fifths of the rounds took effect. From this it would appear that ricochet batteries should, if possible, be placed at a distance of from 400 to 600 yds. from the enemy's works.

The following table is taken from the ricochet practice carried on at Woolwich in 1821. The projectiles were round shot ; the charges and elevations giving the best results have been extracted with the exception of those from the 12 and 9-pr. guns and 68-pr. carronade, as such pieces would rarely be now used for ricochet fire.

TABLE H.

RICOCLET PRACTICE WITH ROUND SHOT.

Nature.	Weight.	Range.	Charge.			Elevation.
			lb.	oz.	prop.	
24-pr. gun.	cwt. 48	yds. 400	0	8	$\frac{1}{48}$	deg. 11
—	—	—	0	12	$\frac{1}{32}$	6 $\frac{1}{2}$
—	—	600	0	12	$\frac{1}{32}$	9 $\frac{1}{2}$
—	—	—	1	4	$\frac{1}{192}$	4 $\frac{1}{2}$
—	—	800	1	8	$\frac{1}{16}$	5 $\frac{1}{2}$
18-pr. gun.	38	400	0	9	$\frac{1}{32}$	6 $\frac{1}{2}$
—	—	600	1	0	$\frac{1}{16}$	5
24-pr. howitzer	12 $\frac{1}{2}$	—	0	12	$\frac{1}{32}$	6 $\frac{1}{2}$
12-pr. do.	6 $\frac{1}{2}$	—	0	10	$\frac{1}{192}$	5 $\frac{1}{2}$

The following table has been taken from the practice carried on by the Cadets of the Royal Military Academy during the years 1857, 58, 59.

TABLE I.  
RICOCHET PRACTICE.

Range 600 yds.

Nature of Ordnance.	Charge.			Elevation.	Fuse.	Projectile.
	lbs.	oz.	Prop.	deg.	inch.	
8-inch gun, 52 cwt.	2	0	$\frac{1}{2}$	$5\frac{1}{2}$		Hollow Shot.
22-pr. gun, 25 cwt.	1	8	$\frac{1}{2}$	$4\frac{1}{2}$		Solid Shot.
do. do.	1	5	$\frac{1}{2}$	$5\frac{1}{2}$		—
10-inch howitzer.	3	0	$\frac{1}{2}$	$6\frac{1}{2}$		Hollow shot.
do. do.	3	9	$\frac{1}{2}$	$5\frac{1}{2}$	-8	Com. shell
8-inch howitzer.	2	0	$\frac{1}{2}$	$6\frac{1}{2}$	-8	—

When the charges are very small, and velocities of projectiles consequently low, wind is found to decrease greatly the accuracy of fire at a range of 600 yards.

Prussian  
ricochet fire  
from field  
guns.

33. The Prussians occasionally employ a kind of ricochet fire from field guns against large masses of troops at very long ranges. For this purpose the axis of the gun is laid horizontally, and the shot when fired, after striking the ground three or four times, proceeds on in short rebounds, not rising above the height of a man; the ground must be open, flat, and hard, for this kind of ricochet, or it may be used on calm water. This fire, depending as it must do; so much on chance, would probably cause little damage, and it would, generally speaking be far more judicious to reserve the fire of your guns till the enemy's troops were within effective range.

Curved fire.

34. When a projectile is fired so as just to clear an interposing cover and then descend upon the object, the line of fire being perpendicular or nearly so to the front of troops or works to be destroyed, such practice has been termed "curved fire" in order to distinguish it from ricochet; it must be evident that the direction of the fire with respect to the object is different from what it is in ricochet, and that no rebounding is necessary in "curved fire," but that the projectile must produce the desired effect on striking the object. This kind of fire has been long employed to dislodge troops posted behind cover by firing common shells from guns or howitzers, but at the present day it receives additional importance, for it would probably be the only effectual way of breaching many of the covered revetments of modern fortresses. Smaller charges and higher angles would (as in ricochet) be required than for ordinary direct fire. In

Art. 61, of this Lecture will be found an example of curved fire in the experiments carried on against Carnot's Wall (Fig 3, Plate 30). The points which it is very desirable to ascertain are,—the ranges and angles of descent suitable for both spherical and elongated projectiles, in order to effect practicable breaches in covered revetments.

*Vertical Fire.*

35. The "laying" of a mortar so as to ensure a correct direction to the shell, is generally accomplished by means of a plummet, which is held in the hand immediately behind the mortar, and the string made to coincide with two pickets or rods placed upon the parapet, and directed upon the object. The pickets *C* and *D* (Fig. 5, Plate 30) are first lined upon the object *B*, the plummet *A* is made to coincide with them, and the mortar is then traversed until the line of the plummet covers the centre line on the mortar, which is denoted by a notch in the muzzle, and another behind the vent; a chalked line being generally drawn on the exterior surface of the mortar between these notches. Should the bed, upon which the mortar rests, be level, this line will be in the same vertical plane as the axis of the piece.

If the platform is in good order and level, the mortar may be laid by means of a line chalked on the platform on each side of the bed, or by a batten of wood nailed to the platform and touching one side of the bed when the mortar is accurately laid; this latter expedient is very useful in night firing.<sup>1</sup>

Inaccuracy of  
vertical fire.

36. The fire of shells from mortars at high angles of elevation, is of all practice the most uncertain as regards accuracy; the reasons of this are, that the shells having comparatively low velocities but long "times of flight," are peculiarly liable to considerable deviations from wind, and other disturbing causes; also that the angles of descent of mortar shells, fired at the usual angle of  $45^{\circ}$  are so great that, unless the object be of some extent, an error in range of a few yards over or under might render the shell useless, whereas when a projectile is fired at a low angle of elevation, so much ground is covered by it before and after grazing that a few yards under or over would not probably prevent it striking the object; the very greatest care is required in weighing out the charges, for if this is performed carelessly, considerable differences will occur in the ranges. In vertical fire, as the object cannot be seen and the piece is generally short, it is very difficult to lay the mortar exactly in the same line for a number of rounds, but if the laying could be performed with the greatest accuracy, still irregularities must

<sup>1</sup> There being no embrasure, the object cannot be seen from the interior of the battery.

always occur in practice with projectiles fired at high angles and with low velocities.

Probable  
accuracy of  
vertical fire.

37. Some idea may be formed of the probable accuracy obtainable by the fire of mortar shells, from the following remarks. Lieut.-Colonel Lefroy, R.A. in a "*Note on Mortar Practice*,"<sup>1</sup> gives a Table of Practice carried on at Woolwich, in the years 1835, 1836, 1837, from which he deduces, "That having a measured distance of 700 yds. it would have been necessary to fire 247 shells to ensure 5 of them falling into a space of 40 ft. diameter.

"The space within which one-half of all the shells fell were as follows:—

	600 yds.	650 yds.	700 yds.
13-inch mortar	70 × 24 yds.	80 × 35 yds.	100 × 32 yds.
10-inch do.	68 × 24 "	"	80 × 32 "
8-inch do.	100 × 32 "	"	170 × 48 "
The whole	79 × 16 "	100 × 36	120 × 40 "

In accounting for this unsatisfactory result, Lieut.-Colonel Lefroy observes that it may in some measure be attributed to the fact that the practice was carried on for instruction, and not for experiment; and he also draws attention to the following better results obtained from practice at Gibraltar, at the end of the last century.<sup>2</sup> One half of the shells fell as under,

Between 900 and 1000 yds. within a space of 60 × 100 yds.			
"	600 "	700 "	30 × 58 "
"	400 "	600 "	15 × 30 "

This practice extended over four or five years, and the mortars used were of the same calibre as the present pattern but longer, and of brass instead of iron. In our Service, mortar practice is generally carried on at a flag-staff, having a circle of ten feet radius described round it, the elevation of the mortar being 45°.

38. Piobert<sup>3</sup> makes the following remarks relative to the accuracy of vertical fire:—

"Firing mortars on the practice ground is generally carried on at the angle of 45°; the object against which it is directed, is a cask raised eight or ten yards above the ground, and supported by a vertical pole, the foot of which forms the centre of two circles of four and eight yards in diameter. The numbers given in the following Table are the result of a very large number of shells fired."

<sup>1</sup> Minutes of Proceedings of the Royal Artillery Institution, Vol. II. p. 13.  
<sup>2</sup> Paper by Captain A. Jardine, dated 1775. "*Records of Military Society*."  
<sup>3</sup> In his *Traité d'Artillerie*.

Probability of Fire of Mortar Shells.

	Calibre of the Mortar.	Distance of the object.	Per Centage of shells which struck the mark.				
			Caa.	Pole.	Small Circle.	Large Circle.	Total.
Practice during 30 years.	12.6	in. yds. 656	0.07	0.18	1.24	2.71	4.20
		547	0.09	0.24	1.55	3.50	5.38
		437	0.10	0.29	4.03	0	4.42
	10.63	656	0.08	0.17	1.18	2.60	4.01
		547	0.07	0.21	1.40	3.12	4.80
		437	0.08	0.26	3.52	0	3.86
	8.661	656	0.08	0.08	0.53	1.16	1.80
		547	0.04	0.11	0.70	1.49	2.34
		437	0.06	0.16	2.44	0	2.66
	5.906	547	0.04	0.14	0.72	1.86	2.76
		437	0.07	0.22	2.27	0	2.66
		328	0.15	0.49	2.96	0	3.60
	Practice during 8 years.	328	0.16	0.50	3.02	0	3.68
		272	0.24	0.77	4.67	0	5.68
		218	0.26	0.88	4.96	0	6.04
		163	0.29	0.94	5.67	0	6.90
		109	0.51	1.54	8.23	0	11.28
		65	0.75	2.45	14.76	0	17.96
		33	0.98	3.17	19.01	0	23.24

“In firing at a powder magazine 38 ft. long, 16½ ft. wide, and 14 ft. high, at the distance of 656 yds. from the battery, the 12.6-in. mortars struck it 4½ times out of 100 rounds at 45° elevation, and 1½ times at 60°; the 10.63-in. mortars struck it 5½ times at 45° elevation, and 3½ at 60°.

“In firing at the epaulment and terreplein of a battery of three pieces, at distances varying from 629 to 700 yds., out of 100 rounds the 12.6-in. mortars struck it from seven to eight times, the 10.63-in. from seven to fourteen times, and the 8.66-in. five or six times.”

Employment of large mortars.

39. By the employment of very large mortars, throwing shells of greater diameter than those now in general use, the accuracy of vertical fire might be greatly increased, as such projectiles would be less liable to deflection and irregularities in range (Art 24, Lecture VII); their momentum and penetration with equal velocities, and the bursting charge would also increase in a much higher ratio than the calibre. The chief obstacles to the use of very large mortars are, the practical difficulties experienced in the manufacture of the mortars and in their transport, and also that of their ammunition, which would necessarily be of great weight, and occupy much space.

Ranges of mortars.

40. The following Tables will shew the charges and lengths of fuze composition for practice with mortars of different calibres.

TABLE I.  
MORTARS.

Range.	13-in.		10-in.		8-in.		5½-in. brass.		4½-in. brass.	
	charge.		charge.		charge.		charge.		charge.	
	fuze.		fuze.		fuze.		fuze.		fuze.	
	lbs. oz.	in.	lbs. oz.	in.	lbs. oz. dr.	in.	lbs. oz. dr.	in.	lbs. oz. dr.	in.
200									2 0	1-55
250									2 3	1-6
300								4 8	2 6	1-65
350								4 12	2 9	1-7
400	1 12	1-8	0 15	1-8	0 9 8	1-8	5 0	1-75	2 12	1-75
450	1 15	1-9	1 0	1-9	0 9 12	1-9	5 4	1-8	3 0	1-8
500	2 1	2-0	1 2	2-0	0 10 12	2-0	5 8	1-85	3 4	1-85
550	2 3	2-1	1 3	2-1	0 12 8	2-1	5 12	1-9	3 8	1-9
600	2 5	2-2	1 4½	2-2	0 13 12	2-2	6 0	1-95	3 12	1-95
650	2 7	2-3	1 6	2-3	0 14 10	2-3	6 4	2-0	4 0	2-0
700	2 9	2-4	1 7½	2-4	0 15 4	2-4	6 8	2-1	4 5	2-1
750	2 11½	2-45	1 8½	2-45	0 15 14	2-45	6 12	2-2	4 10	2-2
800	2 13½	2-5	1 10	2-5	1 0 10	2-5	7 1	2-3	4 15	2-3
850	3 0	2-55	1 11	2-55	1 1 4	2-55	7 6	2-4		
900	3 2	2-6	1 12	2-6	1 2 0	2-6	7 11	2-45		
950	3 4	2-65	1 13	2-65	1 2 12	2-65	8 0	2-5		
1000	3 7	2-7	1 14	2-7	1 3 8	2-7	8 6	2-55		
1050	3 9	2-75	2 0	2-75	1 4 0	2-75				
1100	3 11	2-8	2 1½	2-8	1 4 12	2-8	at 15°		at 15°	
1150	3 14	2-85	2 2½	2-85	1 5 4	2-85				
1200	4 0	2-9	2 4½	2-9	1 6 0	2-9	6 0		4 8	
1300	4 5	3-0	2 6½	3-0			350 yds.		450 yds.	
1500	4 15	3-2	3 0	3-2			0-7 in.		0-8 in.	
1700	5 10	3-4	3 4	3-4			7 0		4 12	
2000					2 0 0		400 yds.		500 yds.	
2400			4 0				0-75 in.		0-85 in.	
2900	9 0						7 8			
							450 yds.		at 25°	
							0-8 in.			
							8 0		4 0	
							500 yds.		540 yds.	
							0-85 in.		1-1 in.	

TABLE M.  
From the Mortar Practice at Sutton, in 1811.  
At 45°.

Range.	13-inch.			10-inch.			8-inch.		
	charge	Time of flight.	Fuze.	charge	Time of flight.	Fuze.	charge	Time of flight.	Fuze.
yds.	lbs. oz.	seconds.	inch.	lbs. oz.	seconds.	inch.	lbs. oz.	seconds.	inch.
400	1 7	9	1-8	0 15	9	1-8	0 9	9	1-8
600	1 14	10	2-0	1 3	10	2-0	0 11	11	2-2
800	2 8	12	2-4	1 8	12	2-4	0 13	13	2-6
1000	3 2	14	2-8	1 12	14	2-8	1 2	15	3-0
1500	4 10	17	3-4	2 6	17	3-4	1 12	19	3-8
2000	6 2	20	4-0	3 2	21	4-2	2 1	23	4-6
2500	8 5	21	4-2	3 14	25	5-0	...	...	...

The times of flight are deduced from those given in the original tables, and the corresponding lengths of fuze have been found by multiplying times of flight by .2.

Rules for mortar practice.

41. The following general rules for mortar practice are here given; although it will be found in practice that the charges of powder for similar ranges will constantly differ, owing to the varying strength of the powder, according to the state of the atmosphere, &c.

13-inch.

The 13-in., with a charge of 3 lbs. of powder, gives a range of 850 yds., and every additional ½ lb. increases the range about 180 yds.

10-inch.

The 10-in., with half the charge of the 13-in. will give about the same range.



8-inch. The 8-in., with about one-third of the charge of the 13-in. will also give about the same range.

The elevation of the mortar for the above must be 45°. At 15° the range is rather more than half that at 45°; at 10° rather less than half, the charges being equal.

Time of flight. 42. For ranges to which the parabolic theory is applicable, the time of flight may be found from the formula,

$$t = \frac{1}{g} \sqrt{\text{range in ft.}}$$

when the elevation of the mortar is 45° (see Formula 3, Art. 2, Lect. VII.), and it was found on reference to the usual Tables for Mortar Practice as in Table L, that the times of flight given are calculated from this formula. At long ranges, the times of flight calculated by this formula will be too short, for the velocities being comparatively high and increasing with the range, the trajectories will differ very sensibly from parabolic curves. On reference to Table M. it will be seen that at a range of 1000 yds. and beyond the times of flight are greater than those calculated by the above formula; and that as the shell is smaller, so the time of flight is longer for equal ranges, at least in comparing the 8-in. with either of the others, and the 10-in. with the 13-in. at 2000 yds. and over. At short ranges, such as those on Woolwich Common, the times of flight as calculated by the formula above, are generally said to be too long, but on service the fuzes of shells for heavy mortars are always required to be "long," so as to give the shells time to penetrate, and that they may not burst on striking, for the useful effect would be thereby almost entirely lost.

Angle of descent.

43. The angle of descent of a mortar shell increases with the initial velocity, which of course depends upon the charge; for, as the velocity increases so will the greater resistance of the air cause the trajectory to differ more from a parabolic curve, the descent of the shell being consequently more nearly vertical as shewn in Fig. 4, Plate 30. The angles of descent are seldom observed, but the following are taken from the experimental practice carried on in 1857 with Mallet's 36-in. mortar:—

At a range of 800 yds. the angle of descent = 45°			
"	"	1650	70°
"	"	2800	80°

The shells generally used being so much smaller than the above, they are more retarded by the resistance of the atmosphere, and their angles of descent for corresponding ranges are therefore most probably greater.

Velocity of descent of a mortar shell.

44. The penetration of a mortar shell depends upon the vertical (or downward) component of the velocity at the moment of striking the ground, and this will of course be due to the fall

of the shell from the highest point of its trajectory. As the range increases it appears, from the preceding article, that the shell descends more vertically, so that at long ranges, the velocity of projection may be considered as practically destroyed, by the time the shell reaches the ground. At long ranges, however, the resistance of the air diminishes no doubt considerably the falling velocity of the shell, although the terminal velocity is perhaps never attained in practice. The falling velocity of a mortar shell at ordinary ranges may be found with sufficient accuracy for practical purposes as follows :—The shell may be assumed to be rising during half the time of flight, and falling during the other half ; therefore, if  $t$  be the time of flight, and  $v$  the velocity required, the latter will be due to  $\frac{1}{2}t$ . Thus for 500 yds.  $t = 10''$ ,

$$\begin{aligned} v &= gt; \\ \therefore v &= 32 \times 5 \\ &= 160 \text{ ft.} \end{aligned}$$

Long ranges. 45. Mortar shells are constantly fired at very long ranges into towns, works, &c.; the following are the charges, the elevation being 45°.

	Charge. lbs.	Range. yds.
13-in., L. S.	9	2800
10-in., L. S.	6	2400
13-in., S. S.		
Charge. lbs.	Range. yds.	
10 .....	2800	
12' .....	3400	
14 .....	3500	
16 .....	3900	
18 .....	4100	
20 .....	4400	
25 .....	4700	
10-in., S. S.		
Charge. lbs.	Range. yds.	
5 .....	2800	
8 .....	3400	
10 .....	3500	
12 .....	3800	
20 .....	4500	

Vertical fire  
from guns.

46. Guns are sometimes used for vertical fire at long ranges, but the results are necessarily very uncertain. In the Crimean war, both the allies and the Russians used old guns for this purpose, but with no very great success.

The following are the charges necessary for the 24-pr. gun of 6½ ft., at 45° elevation,

Charge. lbs.	Range. yds.
3 .....	3500
4 .....	3700
6 .....	4000

For the 24-pr. of 9½ ft. and the same elevation,

Charge. lbs.	Range. yds.
6 .....	4500
8 .....	4800

*On breaching Revetments.*

47. The formation of a breach by means of the fire of artillery, although a subject of considerable importance, has only of late years been reduced to anything like a regular system. Marshal Vauban, indeed, gives various rules for breaching a revetment, in his work on the attack and defence of fortresses, and these have been adopted and improved on from time to time by different engineers and artillerists, but it was not until the present century that such experiments were instituted, as could lead to any very definite results.

Among the precepts laid down by Vauban, none exist as to the time and quantity of ammunition required to make a breach; although we find, that in the commencement of the seventeenth century, it took from about 9000 to 15,000 24-pr. shot to effect this object under ordinary circumstances. It is however to be remarked, that the breaches of that period were much larger than those of the present day, from the fact of their embracing both faces of a bastion, their design being to destroy the salient.

Vauban's  
system of  
breaching.

48. Vauban, in his remarks, appears to recommend that the wall to be breached, should be first cut through in a horizontal direction only, previous to bringing down the masonry by means of salvoes, although it is said, that he also approved of a method, which had been made use of by the Turks, so early as the siege of Constantinople, in 1453. The plan adopted by them was as follows:—They disposed their guns of large calibre, so as to cut the wall first in a horizontal direction, and they then formed two other cuts, making with the first one an equilateral triangle; to overthrow the portion thus cut, they directed upon it the fire of all their guns.

Turkish  
method  
1453, A.D.

Bousmard's  
system.

49. Bousmard's system of breaching a revetment, was very similar to that employed by Vauban, with the addition that at each end of the horizontal, there should also be a vertical cutting; he moreover considered it desirable to make the horizontal cutting as near the bottom of the ditch as possible. At this period, breaching batteries consisted generally of about 8 guns; but during the revolution, and the wars consequent on it, this number was reduced to one-half. The width of the breach was also reduced to what was necessary for the assault.

Gassendi's  
system.

50. General Gassendi advised that a number of vertical cuttings at various distances should be substituted for the

two of Bousmard; and that the horizontal cutting be at the distance of one yard from the bottom of the ditch.

Experiments at Metz, 1834 & 1844, A.D.

51. In 1834, a series of experiments were instituted at Metz, by the French Government, at the instance of M. Piobert Captain in the French Artillery, and again in 1844, at the same place. These, though very satisfactory, were not considered sufficiently complete, and accordingly, a fresh Committee with the Duke de Montpensier as President was appointed in 1847,

Experiments at Bapaume, 1847, A.D.

to investigate the subject at Bapaume, a quantity of the old fortifications of that town having to be destroyed; and it is from these experiments, as well as from those at Metz, added to our former knowledge, that we are now enabled with some degree of certainty to lay down rules for breaching a revetment under different circumstances.

Horizontal angle of fire.

52. The fire for breaching a revetment, should if possible be direct; that is to say, it should not make with the revetment an angle measured horizontally of less than  $50^{\circ}$ , and the harder the masonry the more perpendicular must be the fire, an essential point in breaching being that the shot should not ricochet.

Position and distance of breaching batteries.

53. The position and distance of breaching batteries, will depend much upon the nature of the attack, and of the ground on which these works are to be placed. In general, if practicable, they should be on the crest of the glacis, near the salient of the covered way of the work to be attacked, should it be desirable to breach the salient of the ravelin, a distance usually of from 40 to 60 yards.<sup>1</sup> This, however, cannot always be the case, as may be seen by reference to some of the sieges in the Peninsula, where the distance of the breaching batteries ranged from 450 to 620 yards.

Armament, &c. of breaching batteries.

54. Under ordinary circumstances four guns is perhaps the best number to place in a breaching battery, and none of these should be of less calibre than a 24-pr. It was the opinion of Sir Alexander Dickson, that a 24-pr. of 50 cwt. and 9' 6" in length, was the best gun for all siege purposes. The 32-pr. of the same weight is a good gun for breaching, and might be substituted with advantage for the 24-pr. in all future operations of this nature, until the adoption of a rifled siege gun.

Method of forming a breach.

55. To form a breach, it is necessary to separate that part of the masonry or revetment to be overthrown from the adjoining portion, in such a manner that it may be soon brought down by its own weight, and by the fire directed on it. The best method of effecting this is first to cut the wall in a horizontal direction,

<sup>1</sup> In breaching the face of a bastion, the battery would extend nearly to the re-entering angle formed by the junction of the counterscarp of the ravelin and bastion.

and then vertically at such distances as the strength of the masonry, counterforts, &c. may require. The portions of masonry included between the vertical lines will then have to be broken, and this will be done nearly as much by the weight of the materials as by the shocks of the shot fired against them. In general, the height of the horizontal cutting should be about  $\frac{1}{3}$  the total height of the escarp from the bottom, though in some cases it may be even preferable to make it as much as one-half. The length of this cutting will be regulated by the width of passage required for the assaulting party, generally from 20 to 30 yards.

56. In forming a breach at long distances, such as from 500 to 600 yards, it is impossible to fire with such precision as to be able to regulate the exact height of the horizontal cutting, and consequently it is necessary to commence battering the wall as near as possible to its foot, for otherwise the rubbish from the upper part would accumulate in front of the lower portion of the revetment, and so intercept the fire. Indeed, at long distances such as those above-mentioned, the wall can never be cut through in the same regular manner as at distances of from 40 to 60 yards, and consequently, cannot be brought down *en masse* as in the latter case, but the breach is formed by the bricks or stones which fall successively.

Method of  
forming  
horizontal  
cutting.

57. The best method of forming the horizontal cutting is to divide the length of wall designed to be cut, into as many portions as there are guns in the breaching battery, and for each gun to commence by firing a shot at the outward extremity of the portion of wall allotted to it, and then others at regular intervals until the whole of the horizontal cutting is clearly marked out. The guns will then direct their fire on points exactly between the former ones, and finish by destroying any salient parts of the masonry which may have been left uninjured throughout the line. The falling of the earth of the rampart is generally a good index for showing that the revetment has been penetrated through; as the fall of the revetment and establishment of the breach depend greatly upon the horizontal cutting, this latter is a point of considerable importance. The distances between the first series of shot will vary according to the calibre of the guns in the battery; about 4 feet is the proper space for the 24-pr.

Method of  
forming the  
vertical  
cuttings.

58. The vertical cuttings are formed by first firing a shot a certain distance above the horizontal line, and then another in the centre of this distance; the intermediate salient points are destroyed as before by further firing. A second equal length of cutting is effected in the same manner and, so on, until

the length of the cutting is sufficient. The number of the vertical cuttings and the distance between them must, as has been before remarked, be determined by circumstances, such as the strength and consistency of the materials of which the revetment is composed, the absence or presence of counterforts, and the manner in which these are connected with the revetment. Should, however, this latter be of a weak nature, two vertical cuttings as proposed by Bousmard will suffice; for though necessary in many instances, the intermediary cuttings rather tend to diminish the weight and consequent action of the mass, and fill up the horizontal cutting and middle of the breach with rubbish.

The vertical cuttings need not, in general, be carried to a greater height than one-half the distance between the horizontal line and the cordon, nor need they always penetrate quite through the revetment, as is necessary in the case of the horizontal cutting.

Formation of  
ramp.

59. After the fall of the revetment, shot and shell should be fired to bring down the earth, to form a ramp or road-way into the place; the ramp to be practicable, should not be at a greater angle than  $45^{\circ}$ .

Method of  
forming an  
oblique breach.

60. The only difference in executing a very oblique breach, consists in the manner of forming the horizontal cutting. In this case, as there will be a great probability of the shot's ricocheting, each gun must be directed at that part of its range which is nearest the breaching battery, and a first round will thus be fired. The second round must be also fired at the first holes, in the direction of the horizontal cutting, and so on, until all the openings join and form but one.

Should the masonry be very hard, it would be preferable to direct all the guns at the nearest end of the horizontal line, and work on to the farthest, in order to avoid the loss of too many shot by ricochet.

The French say, that a wall can be breached at the following angles, viz.  $20^{\circ}$ ,  $24^{\circ}$ ,  $33^{\circ}$ , and  $43^{\circ}$ , with charges respectively of  $\frac{1}{2}$ ,  $\frac{1}{3}$ ,  $\frac{1}{4}$ , and  $\frac{1}{5}$  the weight of the shot, and this assertion was established by the experiments carried on at Metz and Bapaume.

In breaching a counter-arched revetment, an oblique fire should be directed on the counterforts, in order to cut them through horizontally. In this case, the vertical cuttings are hardly necessary, as the fall of the arches consequent on the destruction of the piers, would almost certainly cause the overthrow of the revetment even if the horizontal cutting in the outer wall were not continuous.

and precision of the fire; this latter will depend a good deal upon the position of the battery, also whether it is exposed to a heavy fire from the besieged.

65. The differences often observable between the results of experiment and those of actual service, may in a measure be accounted for by the fact, that the former generally take place under the most favourable circumstances, whereas, in the latter, should the gunners be exposed to a very severe fire, they will not be able to lay their guns with the same precision as they otherwise could.

66. The following Tables taken from the "*Professional Papers*" of the Corps of Royal Engineers, the "*Aide Memoire*," and also from the experiments at Bapaume, in 1849, shew the time and proportion of ammunition required to form a breach at some of the principal sieges in the Peninsula; at the siege of Antwerp, in 1832; and also at Metz and Bapaume.

	Guns.	Width of breach, ft.	Shot and shell.	Distance yds.	Time. hrs.
Antwerp. . . .	6 24-prs.	80	1228	55	34
Metz . . . .	4 24-prs.	72	{ 256 including 40 8-in. shells }	35	8
	4 16-prs.	75	{ 325 including 40 8-in. shells }	33	9½

Peninsular Sieges.

Sieges, &c.	Width of Breach in feet.	No. of Shot.	Distance, yards.	Remarks.
1812. Christoval . . . . .	15	1600	450	
Badajoz :—				
Main breach . . . . .	180	14000	540	
Flank do . . . . .	100	9500	530	Wall casemated.
Curtain do . . . . .	40	8000	545	Bad masonry.
Ciudad Rodrigo :—				
Main do . . . . .	105	6700	560	
Lesser do . . . . .	80	2060	570	Bad masonry.
1813, San Sebastian :—				
Main breach . . . . .	100	13000	620	Good masonry.
Lesser do . . . . .	80	5000	620	do.
Addition to breaches . . . . .	300	41000	520	do.

At such ranges as the above, it will of course take a very much greater weight of metal to establish a breach than it would were the batteries at a distance of from 30 to 60 yds.

The above gives an average of 83 hours for a battery of 10 guns to form a breach 100 ft. wide, from a distance of 575 yds., and 92 shot per running foot of breach.

Breaches.	Average Number of Guns.	Total Width of Breaches.	Mean Distances of Batteries.	Time.	No. of Shot per running foot of Breach.	Remarks.
Long Ranges.		feet.	yds.	hrs.		
Badajoz .....	28	320	540	104	{ 83	Brass and iron guns. } Bad masonry masonry.
Ciudad Rodrigo .....	28	135	565	32½	{ 65	
St Sebastian (main and lesser breach)	20	130	620	62	...	
Short Ranges.						
Antwerp .....	6	80	55	34	16	Brass guns.
Metz (average) .....	4	74	34	8½	4	Brass guns.

From the results of the experiments at Bapaume, it was found that to form a breach about 22 yds. in length in tolerably good masonry and under the most favourable circumstances, with batteries of 4 guns, firing charges of  $\frac{1}{2}$ , from a distance of 30 to 35 yds. required

with the 24-pr. 190 shot, and 3 hours 50 minutes.  
" 16-pr. 285 " 4 " 0 "  
" 12-pr. 380 " 4 " 50 "

Advantages of rifled pieces for breaching.

67. The above remarks refer to spherical shot fired from ordinary smooth-bored pieces. With elongated shot from rifled ordnance, no doubt the manner of forming the breach would be but little altered, but the time required, and the number of shot would be less, and the range might be greater than when ordinary round projectiles are used, the accuracy of fire obtained with rifled ordnance being so very superior to that with smooth-bored guns.

Experiments at Eastbourne.

68. The following abstract of experimental practice conducted by the Ordnance Select Committee against a Martello tower near Eastbourne, on the 7th and 8th August 1860, fully confirms the justice of the above remarks.

The pieces used were three Armstrong rifled guns, viz.  
40-pr. of 4·75 in. calibre.  
82-pr. " 6 do  
100-pr. " 7 do

The projectiles fired were

	7-in.	6-in.	40-lb.	Total.
Common shells <sup>1</sup> ....	32	50	50 =	132
Solid shot .....	0	20	20 =	40

172

The battery was 1032 yds. distant from the tower.

A considerable portion of the tower was destroyed by the fire, and a wide breach with a ramp made. A comparison of the

<sup>1</sup> A few of these burst prematurely.



results of fire upon masonry from rifled and smooth-bored ordnance respectively, is given in the following extract from the official Report. "It was calculated that about 6500 cubic feet of brick and stonework were displaced by the fire, amounting to about 362 tons in weight. This was effected at the expense of 1200 lbs. of powder in cartridges, and 650 lbs. in bursters for the shells. The weight of iron thrown was 10,850 lbs. It has been calculated that 10,600 24-pr. shot are necessary to make a practical breach 100 ft. wide in masonry, of average quality from a distance of 500 yds.,<sup>1</sup> which would require about 84,800 lbs. of powder. One-fourth of this quantity may be taken for the purpose of comparing effects in the present case, the breach being, in point of extent, about one-fourth of such a breach as is supposed, but the quality being also inferior, it will be proper to reduce this one-fourth still further, and the Committee assume one-sixth as the basis of comparison.

	Iron.	Powder.
	lbs.	lbs.
Smooth-bored guns, averaging 24-pr. calibre, and weight 50 cwt., at 500 yds. at rubble masonry .....	42,400	14,133
Rifled guns, averaging 80-pr. calibre, and weight 50 cwt., at 1,032 yds. against brick .....	10,850	1,850

"But it must also be borne in mind that the greater part of the expenditure at Eastbourne was occasioned by the 5 ft. of vaulting in the roof of the tower, which it was desired to demolish. A breach 20 ft. wide, measured on curve, was open at the 41st round, where the entire side had fallen, and a very few more shells then directed to breaking up the fragments of brickwork, and smoothing the ramp, would have made it practicable, especially if there had been an earthen rampart or parapet to furnish material to cover them.

"The expenditure of ammunition up to this point was only—  
Iron.....2,953 lbs. against 42,400 lbs. of 24-pr. shot.  
Powder... 511 lbs. against 14,130 lbs.  
when compared with a battery of 24-prs. firing solid shot."

With regard to the accuracy of fire of the guns employed, the Committee's remarks are :—"The precision with which the guns could be directed upon any point it was intended to strike gave them advantages which no smooth-bored ordnance, firing from such a distance, could compete ; and the same circumstances would have rendered it almost impossible to retrench or defend the breach, for the fire might have been continued with perfect safety to the assaulting columns until they were within a very few yards of it, sweeping away all obstacles as fast as they could be laid, and without the slightest interruption from the musketry of the defenders, the battery being quite out of their range."

<sup>1</sup> Aide Memoire, Art. Breach.

Although the masonry was of very good quality, the penetrations of the 40 lb. shot were from 3 ft. 11 in. to 5 ft. 5 in., and of the 6 in. shot from 4 ft. 3 in. to 7 ft. 6 in. The penetrations of plugged shells from the 100-pr., which was not the ordinary 100-pr. Armstrong gun, but a lighter piece termed the 7-in. howitzer, were not so great, being from 3 ft. 2 in. to 4 ft. 3 in.; the displacement of masonry appears, however, to have been greater than that caused by the shot.

69. An experiment was carried on afterwards against another Martello tower from heavy 32-pr. and 68-pr. smooth-bored guns, the range being, about the same, but as might have been expected with very unsatisfactory results compared to the above; for, at a range of 1000 yds. it is impossible with any smooth-bored pieces to fire a number of balls, which shall successively strike very near the same spot; at this range the final velocities of the elongated projectiles will most probably be greater than those of balls, which were fired with higher initial velocities, and the form of an elongated projectile is much more favorable to penetration than that of a ball. The projectiles fired from the rifled pieces were, moreover, heavier than the balls in the latter experiment.

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## RIFLED SMALL ARMS AND ORDNANCE.

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1. THE term "rifle" is generally applied to a small arm; any musket or carbine, the barrel of which is provided with grooves for the purpose of giving the rotatory motion, or "rifle action," as before explained, being called a rifle. When this rifling is applied to ordnance, they are called, "rifled ordnance" or cannon. As the first experiments and improvements in rifling were made with small arms, which have now attained to such great perfection in accuracy, combined with long range, it is advisable, before considering rifled ordnance, to give a short account of the different alterations and improvements successively adopted in the "rifle."

### *The Rifle.*

2. The early form of fire-arms were breech-loaders; some which loaded at the muzzle having been introduced, it was found that the more tightly the ball fitted the bore, the greater was the accuracy of fire obtained; on account, however, of the bore soon becoming foul, the balls required considerable force to drive them down the barrel, which was accomplished by means of a mallet and iron ramrod. It is generally asserted that the grooved barrel was invented by Gaspard Zollner of Vienna, in 1498; the grooves were parallel to the axis of the bore, and intended to receive the foulness from the discharge of the piece, and thus render the loading easier. It was most probably discovered accidentally, that by twisting these grooves round the inner surface of the barrel in a spiral direction, much greater accuracy of shooting was obtained.

Principle of  
rifling  
explained by  
Robins.

3. The cause of increased accuracy by this arrangement of the grooves, was not however understood, until the science of gunnery was thoroughly investigated by Benjamin Robins, who was the first to recognize the great effect produced upon the trajectory of a projectile from the resistance of the atmosphere. A tract was written by Robins, in 1747, on rifled arms, in which he explained the true value of the grooves, and also stated that greater accuracy would most probably be derived from the use of an elongated projectile (egg shaped). At the conclusion of the Tract are the following remarks:—"I shall therefore close this paper with predicting, that whatever State shall thoroughly comprehend the nature and advantages of rifled barrel pieces, and, having facilitated and completed their construction, shall introduce into their armies their general use with a dexterity in the management of them; they will by this means acquire a

superiority, which will almost equal anything that has been done at any time by the particular excellence of any one kind of arms; and will perhaps fall but little short of the wonderful effects, which histories relate to have been formerly produced by the first inventors of fire-arms." The principles demonstrated by Robins, and his suggestions as to the general application of the rifle principle and form of projectile, were not at the time followed out, and it is only within the last few years that attention has been again directed to the subject.

**Baker's rifle.** 4. The first rifle introduced into the British army, generally called Baker's rifle, had seven grooves with a quarter-turn, and was fired with a spherical bullet.

**Rifled-bore with chamber.** 5. In 1827, M. Delvigne, a French officer, proposed a plan, for facilitating the loading of the rifle. The charge of powder is placed in a small chamber at the bottom of the bore, and the ball (spherical) which is made to fit loosely in the barrel, rests upon the shoulder of the chamber (Fig. 1, Plate 31), and is expanded so as to fill the grooves by a smart blow from a heavy ramrod.

This arrangement, which was tried by the 2nd Regiment of the Garde Royale, in Africa, in 1830, was not found to succeed well on service; the edge of the chamber did not afford sufficient support for the bullet, a portion of the powder lodged sometimes on this edge, causing the grooves to foul, and consequently, not to act efficiently on the ball; and lastly, the ball if rammed too hard was disfigured, which greatly affected the accuracy at 220 yds. (See *Rifle Musket*, by Captain Jervis). In 1836, the Brunswick rifle was adopted into our service. It had two grooves with a rapid pitch; the projectile was a belted ball, the object of the belt being to prevent the rifle "stripping," owing to the rapid pitch. With regard to this rifle, Lieut.-Col. Dixon, R.A., in a Lecture delivered at the United Service Institution, remarks, "This was an advance in the right direction, and a positive rotation was thus obtained with certainty. The arm was much improved in shooting, although the loading was not so easy as was required, and a great disadvantage existed in the bullet and cartridge containing the powder, being separate in the soldier's pouch."

**Carabine à tige.** 6. In 1842, Col. Thouvenin (a French officer) invented the "carabine à tige." The "tige" or stem, is made of steel (tempered), and screwed into the centre of the bottom of the bore of the rifle (Fig. 2, Plate 31), round which the charge is placed; the ball enters freely, rests upon the top of the "tige," and is expanded into the grooves by a few blows from the ramrod. But here another defect appeared. The pillar occu-

pying a large portion of the centre of the barrel, and the charge being placed in the annular space which surrounds it, the main force of the powder, instead of taking effect in the axis of the piece, and on the centre of the projectile, acted only on the spherical portion of the bullet which lies over this annular chamber; and thus, the ball receiving obliquely the impulse of the charge, was propelled with diminished force.

Introduction of  
elongated balls.

7. A most important improvement was now proposed (as before stated in Art. 16, Lecture VIII.) by M. Delvigne, viz. the introduction of an elongated bullet. Such excellent results were obtained in practice with this bullet, that it was introduced together with the carabine à tige into the French army of Africa, in 1846; the bullet had a groove round the cylindrical part (*aa*, Fig. 2, Plate 31), by which the cartridge was attached to it, and its point was held in the axis of the barrel by the form of the head of the ramrod.

Prussian  
needle gun.

8. The Prussians adopted a breech-loading rifle with four grooves, usually termed the needle-gun, the projectile for it being of a cylindro-conical form. The chamber into which the bullet is placed is slightly conical for the convenience of loading, and the diameter of the projectile at the shoulder is equal to that of the bore through two opposite grooves; the bullet when fired will therefore be compressed by the projecting lands,<sup>1</sup> and the necessary rotatory motion thus given to it. The projectile has a wooden bottom, in the lower end of which is a small cap filled with detonating composition; in order to ignite this there is a small steel wire .03 in. in diameter at the bottom of the bore and in the axis, which by the action of the trigger is suddenly forced through the charge of powder, and the blunt end striking against the detonating composition in the wooden bottom of the bullet causes it to explode, and thus fire the charge. The mechanism of this rifle is complicated, and could not be thoroughly understood without the aid of very careful drawings.

Minié bullet.

9. As, however, the carbine à tige was inconvenient to clean, the chamber round the tige soon becoming foul, the pillar liable to be broken, and the ramming down of the bullet very fatiguing to the soldier, M. Minie proposed to remedy these disadvantages in the following manner:—The stem was removed from the bore of the rifle, and the bullet made to expand merely by the gas from the explosion of the charge, acting on an iron cup (Fig. 3, Plate 31) placed in a conical hollow, and driving it up into the narrow end of the hollow, thus causing the surface of the cylindrical part to expand into the grooves. A rifle on the minié principle was brought into the service in 1851, but in 1852, a

<sup>1</sup> Lands are the spaces between the grooves.

Committee was appointed by Lord Hardinge, for the purpose of investigating the question of rifled arms, and the principal gunmakers were invited to submit pattern rifles.

Pritchett  
bullet.

10. The bullet finally adopted by this Committee was the Enfield Pritchett, of 1853 (Fig. 4, Plate 31), and is described by Captain Jervis, R.A.,<sup>1</sup> as follows:—

“The expansion of this bullet is obtained by its being made of such a length in proportion to its diameter, that the force of the powder when ignited, acting suddenly against the base, drives it up slightly before the inertia of the point of the bullet is overcome, thus causing it to expand throughout its cylindrical part, and more especially at the shoulder, the most important part being directly over the centre of gravity. The hollow at the base is used more with the view of lightening the bullet, and throwing its centre of gravity forward than to obtain expansion by its means.”

Service bullet  
and plug.

With this bullet, however, the barrel was found to foul, and a plug made of box-wood was proposed by Colonel Hay, Commandant of the School of Musketry, at Hythe, and adopted into the service. With regard to this plug, Colonel Dixon remarks,—“The expansion into the grooves, so ensuring the necessary rotation, is effected at the instant of the inflammation of the charge of powder, in consequence of the upsetting of the lead, assisted possibly by the wood plug which closes the orifice at the base of the bullet, but which no doubt prevents any collapsing of the sides of the bullet when leaving the barrel, a circumstance which would otherwise happen, and thus disfigure the shape, and act prejudicially in other respects. The advantages on the side of the plug are, besides the above, the less frequent fouling of the barrel; in fact, the grooves are cleaned out and lubricated after every shot (Fig. 5, Plate 31).

Principle of  
expansion.

11. The idea of the expansion of the bullet by the action of the charge upon its base was originated by M. Delvigne previous to the introduction of the Minié system, for in a pamphlet, “*Sur le fusil rayé à balle allongée*,” M. Delvigne states as one of the principles of his invention. “To cause the projectile to expand, either by the force of the ramrod, or by the action of the powder in a hollow in the posterior part of the projectile.”

12. Mr Greener, of Birmingham, in a work entitled, “*Gunnery in 1858*,” claims the invention of the expansion system by means of a plug, and also asserts a most important principle, “that the centre of gravity should be in the head of the projectile.”

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<sup>1</sup> The rifle musket.

Whitworth's,  
Lancaster, and  
other bullets.

13. A great many elongated bullets have been proposed by different inventors, viz. Whitworth, Lancaster, Wilkinson, Jacob, &c. (Figs. 6, 7, 8, and 9, Plate 31). The principle of rifling adopted by Whitworth and Lancaster will be noticed in the remarks on rifled ordnance. Very excellent results have been obtained with the rifles of both these inventors.<sup>1</sup> The corps of Sappers are armed with the Lancaster carbine; the chief advantages of this arm are, that considerable range with great accuracy is obtained in practice from it, and as there are no grooves in the barrel, it is not liable to foul, and can be readily cleaned; when tried at Hythe, the Lancaster bullet was found to “strip” very frequently, but this defect has been in a great measure obviated.

14. Wilkinson’s bullet (Fig. 7, Plate 31), differs from other expansive bullets before described, in being solid, having no hollow at the base, but having two deep annular grooves in the cylindrical part. The principle of its expansion is thus described in a pamphlet written by himself.—“Since the projectile has no hollow in the base, the action of the powder upon it, must be different from the minié system, inasmuch as it must drive the ring-formed cylindrical part into and upon the conical fore-end, and so accomplish the filling of the grooves; but this is only possible, providing the conical part of the projectile has the necessary weight.” This bullet has been adopted into the Austrian Service, the Swiss having used a projectile on a similar principle for some time. It possesses the great advantage of simplicity of construction.

15. Col. Jacob, of the Bombay Artillery, has given a description of his projectile in a pamphlet. He obtained with it a very long range, but a large charge is required, the inclination of the grooves is very great, and as will appear by Fig. 6, Plate 31, immense friction is caused by the change in form of the bullet within the barrel.

16. The following Table will shew the relative dimensions, &c. of the small arms successively adopted during the last few years for *general* use in the British Service.

Nature of Arm.	Diameter of Bore.	Number of Grooves.	Spiral.	Charge.	Weight of Arm with Bayonet.	Weight of 60 rounds of ammunition with caps.
	inch.		turn	drs.	lbs. oz.	lbs. oz.
Percussion musket ..... 1842	·753	.....	...	4½	11 3	6 10
Musket rifled ..... 1842	·753	3 & 4	¾	3	11 3	8 9
Rifle musket ..... 1851	·702	4	¾	2½	10 8½	7 0
Enfield rifle musket ... 1853	·577²	3	¾	2½	9 3	5 8

<sup>1</sup> The Whitworth projectile has a very low trajectory, a point of the greatest practical importance.  
<sup>2</sup> The bullet of ·568 in. was reduced by order, dated Feb. 19, 1860 to ·55 in.

From this Table it will be seen that the charge, total weight of arm, and weight of ammunition, have been greatly reduced in the Enfield rifle, while good practice is made with it at 700 or even 1000 yds.; at 200 yds. the practice with the percussion musket was very uncertain.

Lubrifications of rifle bullets.

17. The solid residue from the powder left within the bore after firing would with rifle bores quickly foul the bore to such an extent, that the ramming home of the projectile could not be accomplished, at least without the greatest difficulty. To obviate this, rifle projectiles are what is termed "lubricated" with a substance which shall cause the residue to adhere to the bullet, and be carried out of the barrel by it; in our service beeswax is used for this purpose.

#### *Rifled Ordnance.*

Difficulties in the construction of rifled ordnance and projectiles.

18. Numerous experiments with rifled ordnance have been carried on during the last few years, both in our own country and on the Continent, the long ranges and great accuracy of the elongated bullets from the rifled muskets now in use rendering the successful application of the rifle principle to ordnance a matter of the greatest importance. Very great difficulties arise in the construction of rifled ordnance and suitable projectiles, which can be overcome with comparative ease in small arms and their ammunition.

Lead alone cannot be employed for the projectiles of ordnance, as it is too heavy and expensive, and is also unsuitable for many purposes required of them. Numbers of rifle projectiles have been proposed, some with wings or projections upon them to fit into the grooves of the bore; others of hard material having a coating of soft metal outside, so that the latter may expand or be compressed into the grooves when the gun is discharged. Many other inventions have been tried, but with all, great difficulty is experienced in loading with heavy rifle projectiles at the muzzle, in consequence of which, the breech-loading system has again been resorted to. In the breech-loading guns now constructed, the mechanical contrivances for securing the breech are greatly superior to those formerly employed, and the manufacture of the different parts is more perfect, but doubts are still entertained by some of their being able to resist the successive and severe shocks from continued firing. Sir W. Armstrong's guns, which are breech-loading, have however hitherto stood well, and the Prussians, it is asserted, have been successful in the application of the Warhendorff breech-loading arrangement to their rifled ordnance.

Advantages of breech-loading ordnance.

19. The advantages of loading at the breech with rifled cannon are: (1) That a projectile of larger diameter than the bore can be loaded with ease as in the Armstrong gun.



(2) That the gun can be loaded when run up, the gunners being therefore less exposed. (3) The cleaning of the bore can be more readily effected, and any ignited substance left in the bottom of the bore can be seen and removed.

Cavalli and  
Wahrendorff,  
guns and pro-  
jectiles.

20. In 1846, two rifled cannon were invented, one by Major Cavalli, of the Sardinian Artillery, and the other by Baron Wahrendorff, a Swedish nobleman. Both of these were iron breech-loading guns, having two grooves in order to give the requisite rifle motion to their projectiles. The means by which the breech is closed and secured after inserting the projectile and cartridge is not the same in the two guns. The following account of the arrangement adopted in each is given by Sir H. Douglas, in his work, p. 213; and Major Cavalli has, in a pamphlet, published at Paris, in 1847, described his gun and projectile in detail.

21. "The length of the Cavalli gun (see Fig. 1, Plate 32) is 8 ft. 10·3 in., its weight 66 cwt., and its calibre is 6½-in. Two grooves are cut spirally along the bore, each of them making about half a turn in the length which is 6 ft. 9 in. The chamber, which is cylindrical, is 11·8 inches long, and 7·008 inches diameter. Immediately behind the chamber there is a rectangular perforation in a horizontal direction, and perpendicular to the axis of the bore; its breadth vertically is 9½ inches, while horizontally, it is 5·24 inches on the left side, and 3·78 inches on the right side. This perforation is to receive a wrought-iron case hardened quoin or wedge which, when in its place, covers the extremity of the chamber which is nearest the breech. The projectile being introduced through the breech and chamber into the bore of the gun, and the cartridge placed behind it, a *culot* or false breech of cast-iron is made to enter 2½ inches into the bottom of the chamber behind the cartridge; and a copper ring, which also enters the chamber is placed over it. The iron wedge is then drawn towards the right hand till it completely covers the chamber. After being fired, the gun can be re-loaded without entirely taking out the wedge; for the latter, which is shorter than the rectangular cavity in which it moves, can be withdrawn far enough to allow the new load to be introduced."

22. "The rifled gun constructed by Baron Wahrendorff, differs in some respects from that of Major Cavalli. (See Fig. 2, Plate 32). Its whole length is 8 feet, 10·9 inches, and its greatest diameter *AB* 2 feet, 3·2 inches. The diameter of the bore is 6·37 inches from the muzzle to within 6 inches of the chamber, in which space *cdef* it has a conical form, the diameter at *cd* being 6·95 inches, the diameter of the chamber *cdgh* is 7·5 inches. A rectangular wedge 12·2 inches long, 8·1

inches broad, and 4·25 inches thick (a face of which is shewn at Fig. 3) is made to slide towards the right or left hand in a perforation formed transversely through the breech, for the purpose of covering, after the gun is loaded, the aperture by which the charge is admitted into the bore. A notch 7·2 inches long and 0·7 inch broad is made longitudinally in the wedge, and through this passes the stem or bar of a cylindrical plug, by which the charge is kept in its place. This plug (Fig. 4.) is 7·4 inches diameter, and 4·7 inches long, and it is provided with a stem or bar 15·75 inches long, at the extremity of which is a screw-nut having two handles. The plug is introduced in a direction parallel to the axis of the gun through an orifice in the breech; and its stem passes through a perforation made in an iron door which closes the orifice. When the gun is loaded the door is closed, the plug is pushed forward to the rear of the charge by means of its stem, and the wedge is made to slide into its place; a turn of the screw-nut at the end of the stem is then taken, when the whole is drawn tightly together and is ready for firing. After firing, the wedge is drawn out as far as a pin, which fits into a groove in its top, will permit; and this first allows the plug to be drawn back close to the door which is hollowed, as at *k*, to receive it; the door will then open so that the plug may be withdrawn from the breech of the gun, preparatory to a re-loading being made."

23. "The projectiles are represented in Figs. 10 and 11, Plate 31; the first is designated cylindro-conical, and the other cylindro-conoidal; their entire lengths are  $16\frac{1}{2}$  and  $14\frac{1}{2}$  inches, respectively, and their greatest diameter  $6\frac{1}{4}$  inches; each has two projections *a*, *b*, directly opposite to one another, and  $\frac{1}{4}$  inch deep, which enters the grooves in the rifled bore. These projections make an angle of  $7^{\circ} 8'$  with the axis of the shot." (Sir H. Douglas).

Experiments  
with Cavalli  
and Warhen-  
dorff guns.

24. Experiments were carried on at Shoeburyness, in 1850, with these guns, in conjunction with the service 32-pr. of 56 cwt; the weight of the elongated projectiles from the two former guns being about 64 lbs. With regard to this practice, Sir H. Douglas remarks,—“At the efficient service-elevation of  $5^{\circ}$ , with charges of 8 lbs., the ranges, and also deflections of the different projectiles were nearly equal to one another; and the like is true with charges of 10 lbs. At elevations of  $10^{\circ}$ , the ranges of the foreign guns exceeded those of the English 32-pr., with charges of 8 lbs. by 380 yds.; and with charges of 10 lbs. by 690 yds.; and at elevations of  $15^{\circ}$ , the excess was, with charges of 8 lbs. about 790 yds.; and with charges of 10 lbs. about 1100 yds.

“The deviations were always in the direction of the rotation

of the projectiles ; but they were so variable in amount that no allowance could be made for them in laying the gun with respect to the object. It must be admitted that the Wahrendorff gun has considerable advantages in respect of range, over the English 32-pr. at a high elevation ; but it ought to be observed that the practice is, in that case, very uncertain.

“The Cavalli gun became unserviceable after having fired four rounds, by the copper ring or bouche imbedded in the metal of the gun at the bottom of the bore being damaged. This rendered it necessary to remove the gun to the foundry, in order to have a new copper ring put in ; for this purpose, it was necessary to cut away some of the metal of the gun, in order to set it in the bouche afresh. But, however nicely this was done, it did not succeed, and at the next trial the whole of the breech was blown off. The Wahrendorff gun stood well, the wedge resisting more effectually the force of the discharge than that of the Cavalli gun.” It appears from the above remarks that if the breech-loading arrangement were perfect, very little would be gained by the employment of such rifled ordnance ; in fact, merely an increase of range, at an angle of elevation too high for anything like accurate practice.

The Lancaster form of bore has been termed the “two-grooved rifle in disguise.” Fig. 12, Plate 31 will perhaps serve to explain the above remarks.

Lancaster  
system of  
rifling.

25. The peculiar form of bore for rifled ordnance proposed by Mr Lancaster may be briefly described as follows :—If a gun be bored out cylindrically like an ordinary smooth-bored piece, and two grooves afterwards cut so as to make a quarter of a turn in the whole length of the bore, but with what is termed an “increasing” or “gaining” twist,<sup>1</sup> then if the corners of the grooves be chamfered away, the bore will become elliptical in form. The projectile was elongated, but instead of the transverse section being cylindrical it was elliptical so as to correspond with that of the bore, and consequently the projectile could only pass through the bore by rotating round ( $\frac{1}{4}$  of a revolution) its longer axis. The gun was of course muzzle loading, and therefore had a certain amount of windage ; the shells were made of wrought-iron for the tendency to “jam” in the bore was so great that cast-iron would not stand.

Experiments  
in 1851, &c.

26. An 8-inch gun of 95 cwt. bored on this principal was tried at Shoeburyness in 1851, the projectiles weighing about 75 lbs. The results of this experiment were unsatisfactory, most of the shells breaking either inside or on leaving the bore, and one which remained entire ranged very irregularly to above 800

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<sup>1</sup> The helix is not regular, but the inclination gradually increases from the bottom of the bore to the muzzle.

or 900<sup>0</sup>yds. Better results were obtained in 1852, the projectiles being spheroidal.

In 1854, on the breaking out of the Eastern war, several gun-boats were armed with heavy Lancaster guns (8-inch) having elongated projectiles, while a few light 8-inch guns (52 cwt.) were sent out with the first siege train, and were fired with the ordinary service projectiles.

Experimental practice was carried on at Malta, with two Lancaster guns of 95 cwt. each, in September, 1859; both were fired with a charge of 12 lbs., the bursting charge for the shells being 9 lbs., and the fuzes used were those of Moorsom's pattern. With one gun nine rounds were fired without accident at elevations of from 4° to 5°, the range being 2000 yds. The other gun burst at the 5th round, 2 feet in front of the trunnions, its elevation being 3<sup>3</sup>/<sub>4</sub>° for a range of 1600 yds.

Lancaster guns  
hitherto service  
guns rifled.

27. It is necessary to state here that the so called Lancaster guns are merely service pieces rifled on Mr Lancaster's principle, and not made in any peculiar manner or of any superior material; one strengthened at the chase and muzzle with wrought-iron was fired a great number of rounds at Shoeburyness without injury.

Objections to  
the Lancaster  
system of  
rifling.

28. The principal objections to the Lancaster system of rifling are, that the shell is liable to jam in the bore, and thus cause the bursting of the gun and fracture of the shell; that great irregularities occur in the ranges of projectiles fired from these guns, although the deflections are comparatively constant for similar ranges; also that the projectiles hitherto constructed, although very expensive to manufacture, are less destructive than cast-iron shells. The jamming of the shell in the bore has usually been attributed to the gradual increasing inclination of the grooves, or the "gaining twist" as it is technically called, the injurious tendency of which upon both gun and projectile has been already explained (Art. 29, Lect. VIII.); even with a uniform twist there would be great tendency to jam, for the projectile being slightly elliptical but without any spiral form to correspond with that of the bore, the axes of the projectile and bore cannot be either coincident or parallel.<sup>1</sup> Mr Lancaster has however lately assigned the following cause, viz. that the shells were made of two pieces welded together, the joint was occasionally imperfect, that a portion of gas from the charge penetrated through into the bursting charge within the shell, and therefore that the latter bursting inside the bore fractured the gun. Other and more conclusive experiments are it is said to be

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<sup>1</sup> This objection does not apply to a compressed leaden bullet used with a small arm. It is said that Mr Lancaster is now making projectiles of a spiral form to correspond with the bore of his gun.

carried on at Shoeburyness, with ordnance rifled on the Lancaster principle.

Armstrong  
gun and  
projectile.

29. It is not intended here to enter minutely into the manufacture of the Armstrong gun, but merely to give a general account of the form, construction, &c. of the gun and projectile, and of the principle of rifling carried out by them, which points have been already made public from time to time by Sir W. Armstrong himself.

Gun with  
which the early  
experiments  
were made.

30. Sir W. Armstrong, towards the end of 1854, submitted a proposal for his breech-loading gun to the Duke of Newcastle, then Minister at War; his proposal being accepted, and a gun accordingly constructed, it was submitted to numerous trials both at Shoeburyness, and near Sir W. Armstrong's private factory at Newcastle. The following is a description of this gun: "A core or internal lining was formed of cast steel, to which the requisite strength was given by encircling it with twisted cylinders of wrought-iron made in a similar manner to gun barrels, and tightly contracted upon the steel core by the usual process of cooling after previous expansion by heat; the parts are then in that state of initial tension which is necessary to bring their entire strength into operation (see Art. 50, Lect. II.) The arrangement for loading at the breech consists of a powerful screw having a hole through the centre in the prolonged axis of the bore, through which hole the bullet and charge are delivered into the gun. A 'breech-piece' with a mitred face fitting a similar face at the end of the bore, is dropped into a recess, and by the action of the screw pressed tightly into its seat, so as effectually to close the bore. The fitting surfaces which close the bore were at first made of unhardened steel,—this failed; hardened steel was next used, but this yielded to the action of the powder more rapidly than before; copper was then tried, and no further difficulty was experienced. The breech piece contains the vent. The bore of the gun was  $1\frac{1}{4}$  inches in diameter, and contained 8 spiral grooves having an inclination of one turn in 12 feet; these grooves terminated at a distance of 14 inches from the breech, and the bore then gradually expands in a length of 3 inches, from  $1\frac{1}{4}$  inches to  $1\frac{1}{2}$  inches in diameter."<sup>1</sup> The weight of the gun was about 5 cwt.

Projectile and  
charge.

31. The projectile, a pointed cylinder in form, was made of cast-iron coated with lead, and being of somewhat larger diameter than the bore, could not be put in at the muzzle, but was easily inserted through the breech-screw into the chamber or expanded portion of the bore; when fired the lead is crushed into the grooves, the projectile therefore receiving the requisite

<sup>1</sup> Minutes of Proceedings of Royal Artillery Institution, page 345, communicated by Captain Younghusband, R.A.

rotatory motion, and all windage and the injurious effects resulting from it prevented. The projectile was  $6\frac{1}{4}$  inches long and weighed 5 lbs., and being hollow could be used either as shot or shell. The charge used was one-eighth the weight of the projectile.

**Gun carriage.** 32. The gun carriage was a bracket carriage, somewhat similar to those in the Belgian service, the brackets meeting at the point of the trail. The carriage was provided with a recoil slide and pivot frame; the latter worked by a screw was adapted so as to move the gun horizontally, in order to obtain great accuracy in laying the piece; the recoil slide had an inclination to the rear up which the gun recoiled, and afterwards descending by its own weight the piece recovered its usual position, the object of this slide being to absorb a portion of the force of the recoil, and prevent injurious action upon the pivot frame and adjusting screw

**Experiments.** 33. The following general results were obtained by experiment with this gun. Fourteen projectiles were fired at a butt of wood, 5 feet wide and  $7\frac{1}{4}$  feet high, and at the distance of 1500 yards from the gun; after six were fired as trial shot to obtain the correct elevation, the remaining eight hit the butt without grazing, the elevation of the gun being  $4^{\circ} 26'$ , and the mean deflection from the centre line on the butt was only  $11\frac{1}{4}$  inches.

In order to try the penetration, a block of elm 3 ft. thick, composed of six layers bolted together was placed at the same range, viz. 1500 yards. One shot passed entirely through; another struck near the edge and glanced, and the remaining six penetrated within a few inches of the opposite side. The destructive effect produced by the shell was tested in the following manner.—Two targets were placed covering each other and 30 feet apart, the nearest one being at the same range as before. After some preliminary experiments twenty-two shells were fired at the front target; seventeen hit the first target and burst behind it, three grazed immediately in front of the first target, one hit the bottom of the first target and exploded in the ground, and the remaining one missed both targets and burst beyond. Four shells and three shot were then fired at an elevation of  $6^{\circ}$ , and a range of about 2000 yards. The effect upon the targets was as follows :—The front target contained 51 holes, and the other 164, the ground between exhibiting about 70 perforations. The above results of practice, published by Sir W. Armstrong, will give some idea of the very great accuracy of fire obtained with his gun, and the destructive effect of his projectile at comparatively long ranges; the gun during the firing of 1300 rounds sustained no injury of importance.

Armstrong  
guns for the  
service

34. So far the Armstrong gun was a great success, but the small size of the piece rendered its construction comparatively easy, and it was considered doubtful whether guns of large calibre could be made in a similar manner, great difficulties being always experienced in forging large masses of iron. Sir W. Armstrong has however been successful in the manufacture of ordnance of larger calibres, viz. 12, 25, 40, and 100-prs., which have already been made and withstood the ordinary test of firing, the accuracy of fire obtained from them at long ranges being most remarkable. All these guns for the service are made of wrought-iron alone, the steel lining employed in the original gun of small calibre having been dispensed with as unnecessary (Fig. 5, Plate 32). Each gun is made up of a number of separate tubes from 2 to 3 ft. long welded together, the difficulty of forging very large masses being thus avoided; the tubes are formed by winding long bars of iron, after having been sufficiently heated in a furnace, round a roller so as to form a coil; the details of manufacture are very numerous, and but little idea could be formed of these by a mere inspection of the gun when finished, very great mechanical skill and accuracy being required at every stage. In order to prevent the fouling of the bore and the necessity for constant sponging out, a greased wad is used,<sup>1</sup> and a tin plate, shaped like the top of a canister, is placed in behind the cartridge with the 100-pr. gun, to prevent any escape of gas at the breech. The length, weight, calibre, and other particulars of the Armstrong guns already adopted are given in Lecture III.

Armstrong  
shunt gun.

35. Sir W. Armstrong has been endeavouring to perfect another system of rifling termed the "shunt" principle, which could be applied to either a muzzle or breech-loading piece. The projectile has projections upon it, and the grooves of the bore are broad and flat except near the muzzle, where they are partially filled by a strip of metal, which inclines upwards from the bottom of the groove as it approaches the muzzle. When a projectile passes down the bore of a rifled gun from the muzzle its projections press against one side of the grooves, but on being forced out by the powder they press against the other side, and as in the shunt gun the strips of metal are on the latter, the shot can easily be pushed home from the muzzle, but it will leave the bore fitting tightly, and therefore with its longer axis perfectly steady; for the projections will, as the projectile returns towards the muzzle, have been "shunted" on to the strips; the side of each projection (on the shot) which bears against the groove on issuing from the bore has a piece of copper or zinc attached to it. Experimental practice has been

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<sup>1</sup> The projectiles for these guns are described in Arts. 24 and 30, Lecture VI., the fuses in Art. 48 and 49 of the same Lecture.

carried on with several guns of very large calibre rifled on the "shunt" principle; one, a muzzle-loading piece of 7 in. calibre (the same as the 100-pr. breech-loading gun), but carrying a projectile of 120 lbs. weight, and fired with a charge of 18 lbs., has proved a most formidable weapon against iron plates or slabs.

The Whitworth gun.

36. Mr Whitworth's rifled gun, with which the experiments were made near Liverpool, is also a breech-loading piece, and of the following construction :—The form of bore is that of a hexagonal spiral, the corners of which are rounded off; the inclination of the spiral varies with the diameter of the bore, but is in all these guns very great, the projectiles being comparatively long. The breech is closed by a cap with screws on outside and works in an iron hoop attached by a hinge to the side of the breech; the cap is opened back for loading, after which it is shut to like a door and then screwed on to the breech by a handle for the purpose; the vent is in the centre of the cap, and therefore in line with the axis of the bore. For the smaller natures of guns, Mr Whitworth uses homogeneous iron, the larger guns are made of the same material, but strengthened with wrought-iron hoops fixed on by hydraulic pressure.

Projectile and charge.

37. The Whitworth projectile is hexagonal, its form corresponding to that of the bore, and it is made of cast-iron accurately turned by machinery (Fig. 14, Plate 31); for penetrating hard substances, as wrought-iron plates, the projectile is flat-headed and made of homogeneous iron (Fig. 15, Plate 31). The charge is one-sixth the weight of the projectile, and it is placed in the bore in a tin cartridge which remains in until after the gun is fired when it is removed;<sup>1</sup> a wad of lubricating substance closes the front of the cartridge, and is intended to prevent the fouling of the bore.

Experiments with Whitworth guns near Liverpool.

38. The following Table will shew the dimensions of the guns with which the experiments were made near Liverpool.

Nature of gun.	Bore.		Length.	Weight.	Pitch of Rifling.
	Major axis.	Minor axis.			
	inches.	inches.	ft. in.	cwt. qrs.	1 turn in
8-pr.	1·6	1·48	6 0	1 3·4	3 4
12-pr.	3·1	2·8	7 9	8 0	5 0
80-pr.	5·3	5·0	9 10	80 0	8 4

Very long ranges were obtained from these guns, the 8-pr. at 35° of elevation attaining the extraordinary range of 9688 yds. (more than 5½ miles),<sup>2</sup> but no idea can be formed as to the

<sup>1</sup> This tin cartridge is something similar to that used with the breech-loading fowling pieces.

<sup>2</sup> A projectile fired from the Armstrong 32-pr. gun ranged to a distance of 9130 yds. the elevation of the gun being 35°, and charge 6 lbs.; another projectile weighing 170 lbs. and fired with a charge of 25 lbs. from an immense gun (of 5 tons), rifled on Mr L. Thomas' principle, ranged over 10,000 yds.



Armstrong  
guns for the  
service

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<sup>1</sup> The projectiles for these guns are described in Arts. 24 and 30, Lecture VI., the fuses in Art. 46 and 49 of the same Lecture.

accuracy of fire of a gun at this high angle of elevation; the following results obtained with the 12-pr. at a comparatively short range of 1000 yds. is however very good as regards accuracy. Two shots being fired to ascertain the correct angle of elevation, &c. eight other shots fired in succession all passed through a 6 ft. target within a space of 4 square feet, two passing through the centre of the target.

In these experiments the shot is stated to have deflected very considerably after grazing, this is owing no doubt to its high velocity of rotation. It would be premature to attempt to make a comparison between the results of practice with the Armstrong and Whitworth guns, for experiments are of little value unless they are conducted under similar circumstances; as good practice could most probably be obtained with the Whitworth as with the Armstrong gun, but the breech-loading apparatus of the former is said to be greatly inferior to that of the Armstrong piece.

French rifled  
gun and pro-  
jectile.

39. The French rifled gun has been already explained in Lecture III., it is therefore only necessary to state here that it is a muzzle-loading piece with 6 grooves, their inclination being one turn in 59 in.; the calibre of the field piece is about 3·36 in., the weight of the gun 5 or 6 cwt., and its charge about 1 lb. The projectile is cylindro-conoidal in form, but with a flattened point, and it has two sets of projections or buttons (of soft metal so as not to injure the bore), which fit into the grooves of the bore, one set being round the shoulder and the other round the part near the base (Fig. 13, Plate 31). This gun was used extensively in the Italian campaign of 1859, and as it would appear from both Austrian and French accounts with considerable success. From the principle of its construction its fire is most probably far less accurate and its range less than that of either the Armstrong or Whitworth gun; it has however the advantages of great simplicity in its construction and manufacture, and all ordinary smooth-bored bronze pieces could be rifled in a similar manner, and so save great expense; these reasons were no doubt of sufficient importance to account for its adoption by the French Government, but it is generally considered that bronze guns rifled on the same principle would be very soon injured by rapid firing.

Prussian rifled  
gun and pro-  
jectile.

40. The Prussian rifled ordnance are breech-loading guns,<sup>1</sup> the arrangement for closing the breech being similar to that of the Warhendorff gun already described; a paper wad is however used, which is shaped like the lid of a canister and fits over the

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<sup>1</sup> The information for this account of the Prussian rifled cannon has been derived from the Report of the Artillery Officers, who visited the Continent in 1860, under Major C. Young, R.A.

back of the cartridge, so that when the piece is discharged the wad is forced by the gas against the bottom of the bore, and thus prevents any escape of gas at that part; the wad remains in the piece when discharged and is afterwards pressed by the rammer through the bore, which it therefore cleans out. The safety of the breech-loading apparatus is said to be due entirely to this wad. The grooves are flat and about  $\frac{1}{16}$ th of an inch deep, their number varying from 12 to 18, according to the nature of the gun. The twist is about 1 in 25 ft. The field gun, which weighs 800 lbs. (rather more than 7 cwt.) is made of Krupp's cast steel, its calibre being the same as that of the old 6-pr. gun. Some of the old cast-iron pieces have been rifled, and very good practice has been, it is asserted, made with the 24-pr. cast-iron gun rifled. The charge used for the Prussian rifled ordnance is about  $\frac{1}{10}$ th the weight of the projectile.

The projectile (Fig. 16, Plate 31), is made of cast-iron surrounded with leaden rings, the diameter of the latter being greater than that of bore, so that the lead is compressed into the grooves when the projectile is forced into the bore, rotation being therefore communicated as in the Armstrong gun. The projectile is intended to act as shot, shell, shrapnel, or case; when used as a shot the interior is filled with peas to make up the weight; for shrapnel, bullets with sulphur between them are placed inside the shell. The projectile for the field guns weighs 13 lbs., and that for the rifled 24-pr. guns, 56 lbs.

The Report referred to in the note (on the opposite page) states that good practice was made with the field gun at a target 1100 yds. distant, the elevation of the piece being  $2\frac{1}{4}^\circ$ , and that 15 shot, fired in a recent experiment with  $12^\circ$  of elevation, fell within a rectangle of 60 ft. long by 25 ft. broad, the range being about 5000 paces.<sup>1</sup> As great effect can it is asserted be produced by the fire of the rifled 24-pr. upon a revetment at 1500 yds. range, as by that of the smooth-bored 24-pr. from the crest of the glacis.

Advantages of  
rifled guns.

41. The advantages obtained by the successful employment of rifled guns are,

Great accuracy of fire,  
Long range,  
Penetration,  
Small charge.

That the four first of these advantages are secured has already been shewn in Lectures VII. and VIII., it is therefore sufficient to observe here that a most effective fire is obtained with a comparatively small expenditure of powder; it must however

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<sup>1</sup> A Prussian pace = 30 English inches, nearly.

be remembered that very long ranges of four or five miles obtained at high angles of elevation are nearly practically useless, and only advantageous as criterions of the lowness of the trajectories and consequent accuracy of fire at moderate ranges; in certain cases, as when firing at distant masses of troops, shipping, buildings, &c. ranges of 3000 or 4000 yds. may be attempted, but on the field when troops do not remain stationary and must approach each other, and moreover when the vision is obscured by dust and smoke, very short ranges comparatively are required; also any one conversant with artillery practice must be aware of the very great difficulty always experienced even at ranges of 1500 yds. or less in ascertaining from the battery the distance a shot may have passed over or under an object, and therefore in correcting the elevation.

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## ORGANIZATION, EQUIPMENT, AND APPLICATION OF ARTILLERY.

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General  
remarks.

1. In modern warfare artillery occupies a conspicuous and important position; it is absolutely necessary for the attack and defence of fortresses, and except under very peculiar circumstances is a necessary auxiliary in the field. Artillery, whether employed in field or siege operations, never acts independently, but must be combined with a force of cavalry or infantry; and on the other hand, infantry or cavalry can never produce the same effect if acting alone, as when allied with artillery, which in fact prepares the way for the effective employment of the other arms. Although cavalry or infantry may, by superior and dashing bravery, make up in a great measure for faulty organization and inferior equipment, such is not the case with respect to artillery; everything depends upon the armament and equipment of the latter, as well as upon the skill with which it is employed, and it is therefore necessary to pay the greatest attention to the efficient organization of this arm of the service. Hence, an artillery officer should consider it one of his first and most important duties, to study carefully the nature and power of the arm he commands, the relations of its different branches to one another, as well as the principles upon which are based a good organization of such branches in time of war.

Classification of  
artillery.

2. Artillery may be classed under the several heads of field artillery (including artillery of position), siege artillery, and artillery for the armament of garrisons, fortresses, and coast defences; its equipment is a combination of men, matériel, and horses necessary for these services.

### *Organization and Equipment of Field Artillery.*

3. In order that field artillery may perform efficiently the various duties required during a campaign, it is necessary that it should be well organized and equipped, for otherwise it would prove more embarrassing than useful to the troops of other arms. In consequence of the continual movement of a force in the field, the field artillery are obliged to carry not only a large amount of ammunition but a great variety of stores, so that all repairs of carriages, harness, &c. may be executed without delay; the equipment being very complicated, a good organization is most essential to prevent confusion in the interior management or manœuvring of a battery.

Object of field  
artillery.

4. The object of artillery in the field, is to create disorder and confusion in the enemy's ranks, and thus prepare the way

for the action of the other arms, to support its own troops, to check advancing columns of the enemy, to harass a threatening foe, to cover the retreat of its own army, to defend the key of an important position, and in fact to assist in all the various operations which may be necessary during a campaign.

Field artillery  
organized in  
batteries.

5. Field artillery, that is to say, the artillery which is intended to accompany an army for operations in the field, may be divided into four separate kinds of batteries, viz.,—

Horse artillery batteries,  
Field batteries,  
Position artillery batteries,  
Mountain artillery batteries.

It was formerly the custom to disperse the artillery amongst the infantry at the rate of two pieces per battalion or regiment, thereby rendering it impracticable to employ them for their legitimate purpose, viz. that of concentrating a powerful fire of numerous guns on any important position of the enemy. The other results of this pernicious arrangement were,<sup>1</sup>

(1) The impossibility of a proper surveillance by the general commanding the artillery.

(2) The exposure of the guns to all the risks and accidents that might happen to the corps to which they were attached.

(3) The subordination of the artillery in its movements to the tactics of the infantry, so that when these tactics differed from those of the former corps, it followed that the guns would be badly placed, and

(4) The impossibility of the guns following all the movements of the infantry, and their consequent liability to be often left without support or protection, added to the fact, that the infantry frequently found themselves much hampered and embarrassed by the presence of the artillery, when by a more judicious arrangement, such would not have been the case. These and other minor disadvantages led to a complete re-organization of field artillery, and previous to the commencement of the Peninsular war, a new arrangement was introduced, by which battalion guns were abolished, and the field artillery brigaded distinct from the troops with whom it served, in batteries or troops of six or more guns each. By such a union field artillery became a powerful, destructive, and overwhelming force, inasmuch as the fire of one or more of these powerful batteries could be concentrated on any given point. In addition to this, the whole equipment was simplified and lightened to such a degree, that a battery could move at a rapid pace, a system of manœuvres being introduced, which gave order and regularity to the move-

<sup>1</sup> See Decker's *Traité d'Artillerie*, pp. 262, 263.

ments of artillery, and established uniformity between it and the troops of the other arms.

Armies in the field are organized into brigades, divisions, and army corps. Two or more regiments of infantry or cavalry usually form a brigade; two or more brigades a division; several divisions united under one general an army-corps. As the battalion is the tactical unit of infantry and the squadron of cavalry, so the battery is the tactical unit of artillery. One or several batteries are attached to each division, but in addition there should also be artillery of reserve,<sup>1</sup> the strength of which will depend upon the number of divisions, and the nature of service for which the army is intended. Horse artillery batteries are usually attached to cavalry, and field batteries to infantry; the reserve artillery may be composed of either, with the addition of some position batteries when necessary and practicable. Mountain artillery is only employed in very hilly or mountainous countries.

Number of  
guns.

6. It is impossible to lay down any definite rule for the number of guns that will be required to accompany an army, for although depending to a great extent upon the number of troops of other arms, many different considerations have to be taken into account; as for instance, the general character of the country in which the operations are to be carried on, the means of transport, the nature and equipment of the troops composing the army, and also those of the enemy. When the enemy's troops are badly disciplined or do not fight in large masses, a small force of artillery will suffice, and this also applies when an enemy is chiefly composed of light troops, for in such a case the artillery would be embarrassing to guard and conduct.

Napoleon considered that with old and tried troops two guns to every 1000 men was sufficient, if provided with a large quantity of ammunition, but he also asserted, that if any army is inferior in numbers or badly disciplined, a powerful artillery will make up in a great measure for such defects; we find that he applied this principle in the wars following his disastrous Russian campaign, in which he lost the greater part of his veteran troops. In most of the Continental armies there are usually about three guns to every 1000 combatants. At the commencement of the Seven Years' war, the number of pieces was between two and a half and three per 1000 men, but at the end between five and six. Napoleon's grand army for the invasion of Russia in 1812, averaged about three guns to 1100 men; the French in 1815 had but two per 1000 men; the Anglo-Portuguese army in 1813 had two guns to 1200 men; and the army of occupation in France three per 1000 men. During the Crimean war, the

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<sup>1</sup> No force should be employed without a reserve, which is found indispensable at critical moments to support combined offensive or defensive manœuvres, &c., this maxim applies equally to infantry, cavalry, or artillery.

proportion of field artillery with the British force was not quite two per 1000 combatants. A numerous artillery will always be found to save the troops of other arms, but it will entail a very great amount of transport for its ammunition, stores, &c.

Nature of  
ordnance.

7. The nature of ordnance will depend in a great measure upon the character of the country. Flat open countries are advantageous for the employment of heavy guns and horse artillery, but if the country be hilly, much cut up by enclosures, and not intersected by good roads, it will be almost impracticable to transport the former, and the effective employment of the latter must be naturally much restricted. When there is much cover or the enemy has numerous light troops armed with rifles, shells are indispensable, and therefore the proportion of howitzers or of pieces from which powerful shells can be projected must be large. A great development of shell fire is now required in order to counteract the increased range and accuracy obtained with the present small arms; shrapnel shell has hitherto been looked upon as the most destructive projectile for this purpose, and considerable attention has therefore been turned during the last few years to its improvement, both on the Continent and in England. It is confidently asserted by Sir W. Armstrong, that the projectile for his field piece when it is used as a shrapnel produces a far greater destructive effect than that of any shrapnel shell of similar weight. By the introduction of rifled ordnance, the field howitzers may be abolished as in the French service,<sup>1</sup> in which only one calibre of gun is used both for horse and foot artillery, the equipment and ammunition being thus greatly simplified.

Should it be necessary to defend a number of strong positions, entrenched camps, &c., a considerable proportion of powerful position artillery will be required; on account of their great accuracy of fire at long ranges rifled guns will be most valuable for this kind of artillery, and when made of wrought-iron they will be much lighter than the ordinary 18-pr. cast-iron guns.

Number of  
pieces in a  
battery.

8. The number of pieces in a battery should be determined by what a commanding officer can efficiently overlook and command upon the field of battle. The number varies in the different European armies between four and eight pieces to a battery. In England and France there are six; in Russia, Austria, Prussia, Sweden, Belgium, and some minor European states there are eight; while in the Swiss artillery there are but four. The number eight appears to have some advantages over six, for the extra two guns greatly increase the fire of the

<sup>1</sup> The French by the adoption of the 12-pr. shell-gun greatly simplified the equipment of their field artillery, and at the same time obtained a much more powerful projectile, which was suitable for any gun and battery in the service. As before observed the rifled guns lately introduced into the French service are for the field artillery all of the same calibre.



battery ; a battery of eight pieces can also be divided into two tolerably powerful batteries of four guns each if required ; and each half-battery is composed of two separate divisions instead of one and a half, as with a battery of six guns, and can therefore be more easily manœuvred.

Gun, howitzer,  
and mixed  
batteries.

9. A battery may be composed of guns alone or of howitzers alone, or of both guns and howitzers ; in the latter case it is called a mixed battery. All our horse artillery and field batteries were mixed batteries, so were similar batteries in Austria and Prussia, and also in France until the introduction of the Napoleon 12-pr. shell gun ; our position batteries have usually been either gun or howitzer batteries ; the Belgians, Prussians, and Russians have howitzer and gun batteries. The advantages derived from uniting gun and howitzers in the same battery are,—that such a battery is independent as far as possible, and adapted to all kinds of ground, and every circumstance of combat ; there are however serious objections, viz.—that the effective range of the howitzer and gun differing greatly, as also the objects for which their respective projectiles, common shell and solid shot, are used, the gun will under many circumstances produce great effect when the howitzer is nearly useless and *vice versa*, so that one nature of piece must be sacrificed for the other (see Art. 32, Lecture III.) These defects are avoided by the introduction of rifled guns of only one calibre for horse artillery and field batteries, the power of all the pieces in a battery being then similar.

Ammunition  
for field service.

10. The ammunition for service in the field is carried in the gun wagons and ammunition wagons ; and during the war in the Crimea, spare ammunition for the field batteries and horse artillery was also conveyed by the small arm brigades, though not in any very large quantity.

The ammunition hitherto supplied to field guns has been solid shot, case, and shrapnel shell ; to howitzers, common and shrapnel shell, and case ; to every battery there is also a considerable supply of rockets, which are carried in a carriage for the purpose. With the Armstrong field piece only one projectile is issued, which can be used either as shot, shrapnel, or case.

The number of rounds per gun is based on that which is deemed sufficient for a considerable action. At the battle of Lutzen, which the French gained over the allies in 1813, about 220 rounds were fired from each gun, and upon this they base the amount of ammunition required for field guns. When the proportion of field artillery with an army is considerable, the quantity of ammunition to be transported is enormous, as it is always necessary to provide against the contingency of a great

battle ; thus, although at the battle of Leipzig in 1813, the French artillery had 220,000 rounds, this immense supply was not found adequate.

The number of rounds conveyed into the field by the different natures of guns in the British service, is as follows :—

18-pr. iron gun.....	180
42-pr. (medium) brass gun .....	144
32-pr. brass howitzer .....	149
do. (battery of howitzers alone)....	176
9-pr. brass gun .....	176
24-pr. brass howitzer.....	174
6-pr. (light) brass gun.....	268
12-pr. brass howitzer.....	286
12-pr. Armstrong rifled gun <sup>1</sup> .....	213

By a recent order (20th March, 1861), the officer commanding the Royal Artillery, whether in the field or in garrison, is held responsible for the preservation and transport of small arm ammunition for the troops. For an army in the field the first and second reserves are both with the Royal Artillery, the third and great depôt being in charge of the Military Store Department. The first reserve is to be conveyed in artillery small arm ammunition wagons,<sup>2</sup> and attached to the field batteries with each division ; each wagon is provided with cradles and ladders to admit of leading horses being made use of in transporting the ammunition to any positions, which may be impracticable for wagons. The second reserve is also carried in small arm ammunition wagons, and must always be up with the army, but kept as far as practicable out of fire. The third reserve must be within two days' march of the army.

Animals  
employed for  
field artillery  
service.

11. In India, camels, oxen, and even elephants, have been and still are used for the purposes of field artillery, and where horses cannot be obtained it is well to have such animals to fall back on ; but the horse, even though of a small breed is to be preferred, and there is no doubt but that much greater execution might have been done in many of the actions during the Indian rebellion, had the guns been horsed, instead of being drawn by bullocks or elephants, as was the case in some instances.<sup>3</sup> Mules have been found to be very useful animals for artillery purposes, and especially for horsing the spare wagons, &c.

<sup>1</sup> Supposing a battery of 6 rifled pieces to have 12 ammunition wagons instead of 11, like a 9-pr. battery.

<sup>2</sup> Six small arm ammunition wagons to each battery.

<sup>3</sup> See Reports from Col. D. E. Wood, R.H.A. dated, "Allahabad, Jan. 6, 1858;" and "Head Quarters, Camp Force, under Major-Gen. Sir James Outram, G.C.B., March 6, 1858;" also Captain Palmer's Report, dated, "Camp, Bandah, April 21, 1858."

The number of horses allowed per gun on service in the British Royal Artillery, is six per light 6-pr. gun and 12-pr. howitzer, or per 12-pr. Armstrong gun, and eight per 9-pr. (medium) gun and 24-pr. howitzer. In the French service, six horses is the number allotted to their field guns, as they consider that a larger number cannot be made to work together efficiently.

#### *Horse Artillery.*

Purposes for which horse artillery is used.

12. Horse artillery is usually attached to cavalry, being able to accompany that arm in its most rapid movements, owing to the circumstance of the gun detachments being mounted. It is a most useful branch of the service in the field, being peculiarly adapted for advanced guards, skirmishes, reconnaissances, and for covering the retreat of an army, as it can hold its ground with safety longer, and can retire more rapidly than a field battery could do under the same circumstances. Horse artillery is also well calculated to form part of the artillery in reserve during an action, as it can be brought to the front at a rapid pace, and without delay. Cavalry forms the usual support to horse artillery.

First introduction of horse artillery.

13. This description of field artillery was first organized by Frederick the Great, in 1759, during the Seven Years' war, and although twice destroyed, at Kunersdorf and Maxen, it was re-organized in the year 1760, when it consisted of six light 6-pr. and two 7-pr. batteries. In 1778, the number of horse artillery batteries in the Prussian service was seven, and in 1806 as many as twenty; at present there are twenty-seven, this large number being necessary as this kind of artillery forms the chief part of the reserve.<sup>1</sup> Horse artillery was introduced into the French service in 1791, where it rendered many important services during the long wars of that period. The four first troops of British horse artillery were formed in 1793.

Armament of horse artillery batteries, and proportion of horse artillery to field batteries.

14. Batteries of horse artillery in our service have been armed with the 9-pr. (medium) brass gun and with the 24-pr. howitzer, and others with the light 6-pr. gun and 12-pr. howitzer; but the 12-pr. Armstrong rifled gun of 8 cwt. is now being supplied to all such batteries; as however the total weight of gun, carriage, and ammunition is too great for rapid movement (see Table Art. 19, Lecture IV.), a projectile weighing 9 lbs. will probably be substituted for the ordinary 12 lb. segment shell, for the horse artillery rifled pieces; they all carry a certain proportion of Congreve rockets, in a rocket carriage.

The proportion of horse to foot (field) batteries in some of the different European armies is about as follows :—

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<sup>1</sup> On the use of field artillery, by Taubert, captain in the Prussian artillery.

	Horse.	Foot.
In France, as 1 to 7		
„ Russia, „ 1 „ 4		
„ Prussia, „ 3 „ 8		
„ England, „ 1 „ 6		

The details of batteries will necessarily depend upon the nature of the service for which they are intended, but the following Table is given as an estimate of what might be required for a battery ordered on active service; the detail of a 12-pr. Armstrong battery would differ but little from this Table, except that there would probably be 12 instead of 11 ammunition wagons.<sup>1</sup>

Detail of a 9-pr. Battery, Royal Horse Artillery, for Active Service (as with the army in the Crimea).

No. of Carriages.	Equipment.	Men.			Horses.		
		Gunners.	Drivers.	Total.	Riding.	Draught.	Total.
4	9-pr. guns .....	40	16	56	40	32	72
2	24-pr. howitzers .....	20	8	28	20	16	36
6	Gun ammunition wagons.....	12	18	30	4	36	40
5	Howitzer ammunition wagons.....	10	15	25	2	30	32
1	Store limber wagon .....	3	3	6	6	6	12
1	Spare gun carriage.....	3	3	6	6	6	12
1	Forge .....	3	3	6	6	6	12
1	Rocket carriage .....	4	4	8	8	8	16
1	Store cart .....	1	1	2	2	2	4
1	Medicine cart .....	1	1	2	2	2	4
2	Forage wagons .....	4	4	8	8	8	16
3	Water carts .....	3	3	6	6	6	12
	Officers' horses .....			12	12		12
	Bat horses .....				6	6	12
	Horses for 2 staff-serjeants, 2 trumpeters, } 1 farrier, 3 shoeing-smiths .....			8	8		8
	Spare horses.....			6	18	22	
	Spare men, officers' servants, and batmen	15	44	59			
28	Total carriages.....	97	123	220	92	180	272

Officers .....

Non-Com. Officers and Men.

Artificers ...

Captain .....

Second Captain...

Lieutenants .....

Assistant-Surgeon

Staff-Serjeants ...

Serjeants .....

Corporals .....

Bombardiers .....

Gunners .....

Drivers .....

Trumpeter .....

Farrier .....

Shoeing-Smiths...

Collar-Makers ...

Wheelers .....

1

1

3

1

2

8

4

6

97

123

1

1

6

3

2

AMMUNITION.

4 gun limbers

6 gun ammu. wags.

2 how. limbers.

5 how. ammu. wags.

round shot

shrapnel

common case

round shot

shrapnel

common case

common shell

shrapnel

common case

common shell

shrapnel

common case

carcasses

Total, 516 rd. st., 108 shr., 80 c.c.

Tot. 136 os., 174 shr., 28 cc. 10 car.

Rockets, 12-pr.

73

24

32

444

84

48

16

24

8

120

150

20

10

100

Total... 259

For home service a 9-pr. battery of horse artillery has 18 carriages, 90 gunners, 85 drivers, and 180 horses.

<sup>1</sup> The detail for an Armstrong battery has not yet been definitely laid down.

*Field Batteries.*

Purposes for which field batteries are used.

15. The field batteries<sup>1</sup> form the great bulk of the artillery which accompanies an army for active operations, and they are especially suitable for manœuvring with infantry, although by mounting the gunners on the carriages, they can move with sufficient rapidity to keep up with cavalry. They are however usually required to remain in one position on the field for some time, at least in well contested actions, and in taking up fresh ground need not generally go beyond an ordinary trot; in short and decisive affairs, in the retreat of a force, &c., rapidity of movement will be of the greatest value in field batteries, especially if the number of horse artillery guns be small. The ammunition boxes of the gun limbers and wagons are so arranged as to be able to receive the gun detachments, and by an order of H. R. H. the Duke of Cambridge, Nos. 1 and 6 are on all occasions to be mounted on the limbers, their knapsacks being strapped to it. The other numbers of the detachment are also to be mounted, but carrying their knapsacks when the battery is advancing in line at a review or inspection, in marching past, and during rapid movements and evolutions.

16. Field batteries were not organized as at present until the beginning of this century, and after the formation of horse artillery. Previous to this their organization and equipment was very defective, the pieces were too light, they were mounted on badly made carriages drawn by horses in single team, the drivers were on foot, and provided with large whips like ordinary carters, and the ammunition was carried in rough wooden boxes.

Armament of field batteries.

17. At the commencement of the Peninsular war, the field batteries consisted of 3 and 6-pr. bronze guns, and 5½ and 4½-in. bronze howitzers, but at the end of this war 9-pr. guns and 24-pr. howitzers were substituted for the lighter pieces; the Armstrong rifled gun of 8 cwt. is now being supplied to all field batteries.

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<sup>1</sup> Called foot batteries on the Continent.

Detail of a 9-pr. Field Battery, Royal Artillery, for Active Service.

No. of Carriages.	Equipment.	Men.			Horses.			
		Gunnery.	Drivers.	Total.	Riding.	Draught.	Total.	
4	9-pr. guns	40	16	56	...	32	32	
2	24-pr. howitzers	20	8	28	...	16	16	
6	Gun ammunition wagons	12	18	30	...	36	36	
6	Howitzer ammunition wagons	10	15	25	...	30	30	
1	Store limber wagon	...	3	3	...	6	6	
1	Spare gun carriage	...	3	3	...	6	6	
1	Forge	...	3	3	...	6	6	
1	Rocket carriage	...	4	4	...	8	8	
1	Store cart	...	1	1	...	2	2	
1	Medicine cart	...	1	1	...	2	2	
2	Forage wagons	...	4	4	...	8	8	
3	Water carts	...	3	3	...	6	6	
	Officers' horses	...	...	...	6	...	6	
	Bat horses	...	...	...	...	6	6	
	Horses for Staff-Serjts., Mounted Non-Com. Off., 2 Trumpeters, 1 Farrier, and 1 Shoeing-Smith	...	...	...	18	...	18	
	Spare horses	...	...	...	2	20	22	
	Spare Men, Off. Servants, and Batmen	15	24	39	...	...	...	
28	Total carriages.	Total	97	103	200	26	184	210

		AMMUNITION.				
Officers .....	Captain .....	1	9-pr.	4 gun	round shot .....	73
	Second Captain ...	1		limbers.	shrapnel .....	24
	Lieutenants .....	3			common case ...	33
	Assistant-Surgeon	1				
Non-Com.	Staff-Serjeants ...	2	9-pr.	6 gun	round shot .....	444
	Serjeants .....	8		ammun.	shrapnel .....	84
	Corporals .....	6		wags.	common case ...	48
	Bombardiers .....	7		Total, 516 rd. st., 108 shr., 80 c.c.		
Officers and Men.	Gunnery } .....	200	24-pr.	2 how.	common shell ...	16
	Drivers } .....			limbers.	shrapnel .....	24
	Trumpeters .....	2			common case ...	8
	Farrier .....	1				
Artificers ...	Shoeing-Smiths ...	6	24-pr.	5 how.	common shell ...	120
	Collar-Makers ...	3		ammun.	shrapnel .....	150
	Wheelers .....	2		wags.	common case ...	20
					carcasses .....	10
Total.....		243	Tot. 136 ca., 174 shr., 28 cc., 10 car.			
			Rockets, 12-pr. .... 100			

For home service a field battery has 17 carriages, 100 gunners, 75 drivers, and 104 horses.

Batteries of Position.

Objects for which position batteries are used.

18. Batteries of position are designed for the defence of posts, entrenched camps, lines, &c. and for the occupation of important positions on the field of battle. They may also be used as a means of connecting the different forts and batteries which may be situated on any coast. When used in offensive operations, this species of artillery becomes artillery of reserve, to be brought forward at critical periods of the attack.

Armament of position batteries.

19. Batteries of position have been composed of 12-pr. brass guns, 32-pr. brass howitzers, or of 18--pr. iron guns (38 cwt.), and 8-inch iron howitzers.

If of brass, the battery will generally consist of six pieces; if of iron, of four only. In consequence of the superior power and large calibre of these pieces, their round shot are most formidable

against the enemy's artillery, while their shell and case cause great destruction among large masses of troops.<sup>1</sup> It is likely that before long, the above-mentioned guns of position will be replaced by rifled ordnance (probably the 25-pr.), which, possessing not only superior power, but also considerably less weight of metal, will give to batteries of position a greater degree of efficiency and mobility than they have hitherto possessed.

Organization  
of position  
artillery.

20. All field artillery may be said to have been artillery of position previous to the Seven Years' war, for with the exception of a few isolated cases, it possessed little mobility, and usually remained during an action in one position without attempting to manœuvre; it generally opened an engagement, and almost invariably became the prey of the victor. After the field artillery was lightened and rendered capable of rapid movements, artillery of position then became reserve artillery.

Two or three batteries of 18-prs. were equipped for field service as guns of position previous to the battle of Waterloo, but were not present at that engagement. 18-pr. iron guns and 8-inch iron howitzers were sent out to the East in 1854, as guns of position, and were employed in the defence of the lines of Inkermann and Balaklava. Two of the 18-prs. were brought into action at the battle of Inkermann, and did great execution in that engagement, contributing in no small degree to the success of the day.

In 1855, two heavy batteries were sent out to the seat of war, the one composed of four 18-pr. iron guns, the other of a like number of 32-pr. brass howitzers; they were fully equipped and horsed, and were intended as guns of position. The 32-pr. battery was engaged during the action on the Tchernaya, on the 16th August, 1855, and was horsed in the ordinary manner; but with regard to the 18-pr. battery, such was not the case, for twelve horses was the number allotted to each gun, and these were harnessed four abreast, the drivers being mounted on the near and off horses; this method has been adopted with this species of battery of position.

Guns of position, more particularly the iron pieces, require when horsed a much larger and stronger stamp of animal than that necessary for ordinary field guns; size and power rather than activity should therefore be looked to in their purchase, as these guns are not intended to execute rapid manœuvres; the strongest men should also be posted to them as gunners, on account of the

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<sup>1</sup> In the Prussian service three 12-pr. batteries of 8 guns, are attached to each army-corps. The Prussian 12-pr. is rather longer and heavier than the British 12-pr.; its calibre is a little larger, and it is fired with a larger charge of powder.

B. 12-pr. 17 cal.; 18 cwt.; cal. 4.62 in.; charge 4 lbs.

P. 12-pr. 18 " 20 " " 4.67 " " 4.55 lbs.

Sweden, Belgium, and Sardinia have heavy batteries similar to those of Prussia.

weight of the trail, and the having to shift the piece from the travelling to the firing trunnion holes and *vice versa*.

### Mountain Batteries.

Purposes for which mountain batteries are used.

21. When operations are carried on in a mountainous country, or in one inaccessible to ordinary artillery carriages, a very light description of ordnance and equipments can alone be employed, and this only in a very limited quantity, on account of the great difficulties of transport, and also from the fact, that in mountain warfare, a large proportion of such artillery would considerably hamper the force to which it was attached, without even compensating for the inconvenience, &c. attendant upon its escort.

Equipment, armament, &c. of mountain batteries.

22. There are two kinds of mountain batteries used in our service, in the one most frequently employed, the whole of the material is conveyed on the backs of mules or horses; in the other, single draught is made use of for transporting the guns and their carriages, the shafts being attached to the point of the trail. When the nature of the country will admit of it, the latter plan is to be preferred, as the former method of carrying the guns, is open to the objection that the animals are very liable to sore backs and galled withers from the nature and disposition of their burthen. Two mules per gun or howitzer are required in either case, as with the first named species of battery, one mule carries the gun, and the other its carriage; and with the second, the team consists of two mules, the one in the shafts, and the other leading. The ammunition boxes are in both instances carried on mules' backs.

Mounted batteries in our service have generally consisted of four pieces, viz. three guns and one howitzer, the former being the 3-pr. guns of 2½ cwt. and the latter the 4½-inch howitzer of 2½ cwt., but the 6-pr. Armstrong rifled gun is intended to supersede these pieces.

Two mules per gun and three per howitzer are allowed for carrying the ammunition, the batteries in draught conveying 168 rounds per gun and 96 per howitzer, and the other description of battery 120 rounds per gun, and 72 per howitzer. This difference is owing to the circumstance that in the former case, the leading draught mule carries a certain proportion of ammunition.

The French use howitzers alone for mountain service, six pieces to a battery, and each battery carries with it 14 rounds per howitzer, and 40 to 50,000 rounds of small arm ammunition for the troops of the line. It seems preferable, however, that mountain batteries should have, as with us, a reduced number of pieces from the circumstance that they can be but seldom



employed together, and from the obstacles with regard to escort and transport before mentioned.

*Application of Artillery in the Field.*

23. The equipment and organization of field artillery having been already explained, it remains to consider briefly the application of this branch of the service in time of war, and to give some general principles with regard to the management of artillery on the march, in action, &c. Field artillery to be really effective, should combine accuracy and quickness of fire with considerable celerity of movement; the former of these will depend on the instruction and general efficiency of the officers and men composing the battery, as well as on the nature of the guns employed, and the latter will be secured by having the carriages of suitable construction and well horsed, for otherwise artillery becomes a troublesome and sometimes even a useless appendage to an army.

Marches and  
convoys.

24. Before artillery can be employed upon the field of battle, it is necessary to march and generally to encamp in an enemy's country, and no part of an artillery officer's duty requires more care or attention, even to the minutest details, than this does, as the slightest fault or negligence may entail the gravest disasters. The officer commanding a convoy or battery should examine closely into the exact state of his charge, and ascertain that nothing be wanting; that the horses and carriages are in a fit and proper condition for the march, and that the ammunition is perfectly serviceable.

25. An escort is necessary for the safety of a convoy when travelling in an enemy's country, and should be chiefly composed of infantry; if there be a deficiency of this arm the gunners must to some extent supply its place. A battery marching by itself should always have an advanced guard; in a narrow road, the latter should be considerably in front to stop all carriages which might cause obstruction; in a hilly road it should reconnoitre the top of every hill, and see that all is clear before the guns come up.

26. When on the march, a halt of ten minutes or quarter of an hour should be frequently made, not only to rest the horses, but also to allow any carriages which may have dropped a little to the rear to recover their distance. In long ascents, a halt should be made from time to time and the wheels scotched, in order to rest the horses, there should also be a greater interval between the carriages. In descending a hill the drag chain or shoe must be used, and should not be taken off until the horses have to recommence drawing; these operations should be per-

formed without loss of time, seeing that the stoppage of each carriage retards the whole battery or convoy. In passing through villages or other inhabited places, precautions must be taken against fire, more especially if there be with the convoy, wagons laden with barrels of powder. When halted for any length of time, the horses of the carriages and wagons should not be unharnessed, and the same precautions should be taken as upon the march, viz. to reconnoitre the surrounding ground, woods, villages, &c.

27. In case of an attack when *en route*, the carriages should close up and the convoy continue its march, while the escort falls in and shows front to the enemy. Should however the battery or convoy be closely pressed, and that there are hopes of support, a square should be formed (if the road will admit of it) of the carriages with the guns at the angles, the escort sheltering itself behind the first line of wagons, and from thence keeping up a fire upon the attacking party. In night marches, where there is a chance of an attack, strict silence should be observed; the men should not be allowed to call to one another, nor to make any noise in cracking their whips, nor should any lanterns or matches be lighted, for on a dark night the smallest spark may be seen a considerable distance.

28. When an accident happens to a carriage either on the march or in manœuvring, those in its rear should pass it on the most convenient flank and fill up its interval; it can resume its place as soon as the damage has been repaired. A wagon belonging to a disabled gun should always remain with it, and a gun must not wait for its disabled wagon, but only leave a sufficient number of men to repair it.

29. When it is necessary for artillery to cross a river, a reconnaissance must first be made to ascertain the exact position of the fords, which are usually situated at the rapid parts of the stream. Artillery can cross a river of the depth of about three feet and a half, much however depends on the strength of the current. When the water is deep and the current strong, great attention must be paid in fording, and the leader of the column should keep his eye steadily fixed on some point or object on the opposite bank, which may serve to mark the direction of the ford, as otherwise, he is likely to be deceived by the appearance of the water, which seeming to carry him down, might induce him to keep too high up the river, and so miss the ford. No carriage should be allowed to swerve in the least from the line marked out by the leader, nor should any of the horses be allowed to halt, trot, or drink, while crossing.

30. In marching in a hilly country, and particularly where

the road passes through ravines and defiles, great care should be taken to prevent surprises, and to avoid ambushes, to which the nature of such ground is particularly favourable. A ravine or defile should be passed as quickly as possible, whether the column be in retreat or otherwise, as it is a hazardous operation in an enemy's country, and as artillery can seldom be made available in any way while passing through. Should a division be retreating along a road or through a defile between hills, some of the guns should halt on the top of the hills, and protect the retreat of those in the hollow; in these cases, round shot may be fired with safety to the retreating troops, and perhaps with good effect against an enemy. In retrograde movements, the ammunition wagons should be sent to the rear, though two or three may be kept nearer than the others to supply ammunition, and on emerging from a defile, it should be ascertained that no carriage or wagon has been left behind.

**Encampments.** 31. The position of a camp depends in a great measure upon the plans of the General in command, and these will be modified by the nature of the ground, and by the disposition of the enemy's troops, if such are at hand. In choosing the site for a camp, it should be ascertained that a tolerable supply of water may be procured, as upon this depends not only the comfort, but also to a great extent the efficiency of the battery or brigade of artillery; for horses regularly supplied with a sufficient quantity of water, will be enabled to do much more work than if the reverse be the case. Should the ground to be occupied be near a village, the camp should be pitched if possible to windward of it, and at the distance of at least one hundred yards, in order to avoid danger from fire. While in camp, advantage should be taken of the spare time to re-examine the state of the horses, carriages, stores, &c., and to repair any damage which may have occurred upon the line of march. In encamping and picketing, strict attention should be paid to the system laid down, as not only is nothing gained, but on the contrary much time is lost, by performing any such duty in a hurried or slovenly manner (Plate 34).<sup>1</sup> In encamping on the march in an enemy's country, the men should not be permitted to stray away from the camp and its vicinity, and precautions should be taken against surprise while the horses are being watered.

**Choice of ground.**

32. The choice of the most favourable ground for each arm of the service being of the greatest importance with regard to the eventual result of an action, it is necessary that commanding officers of artillery should precede their batteries in order to examine the ground which is to be taken up by their guns. In

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<sup>1</sup> Extracted from Field Battery Exercise.

action, the second captain generally remains in charge of the ammunition wagons, &c. which should keep in the rear, and be sheltered as much as possible from the enemy's fire though they should not be at so great a distance as to be unable to supply the guns with fresh ammunition when required, but conform to the movement of their battery in such a manner as to be able to do this efficiently.

33. In choosing a position upon the field for artillery, the following principles should be chiefly borne in mind, viz. that the guns should command not only the approaches to the weakest points of the position, but also if practicable, the whole of the ground within their range; that they should not inconvenience the manœuvres of the troops they support, and that they should be as far removed, as circumstances will permit, out of the range of any place which might afford a shelter for the enemy's infantry, and from whence the latter could harass the gunners. If this, however, be impracticable, one or more guns must be told off to keep down the enemy's fire. When guns are placed to defend a position, to protect troops in passing a river, &c. it is always advisable that the batteries should be at some distance from each other, but should at the same time be able to concentrate and cross their fire on the ground in front.

34. Besides the foregoing, it is also necessary to consider in some degree the formation of the ground and nature of the soil, not only of the part of the field the battery or brigade is to occupy, but also of that surrounding it. For precision in firing, the ground on which the guns are posted should be tolerably level, and should not have too great a command over the space which the enemy must cross over to the attack, as a plunging fire is little destructive. A gently falling slope of not more than 1 in 15 is to be preferred; the fire of artillery produces the most effective results on a slope of about 1 in 100. Batteries should not be placed on stony ground, as the enemy's shot make the stones fly in all directions, often causing considerable damage; marshy ground in front of a battery is good, should the latter not be likely to advance, as the shot will either penetrate or ricochet but little from it; undulating ground prevents the enemy in a great measure from observing the grazes of his shot, and thereby rectifying his fire.

35. No position should be occupied by artillery from which it could not retire with facility, and a Commanding Officer should take every opportunity of making himself personally acquainted with the adjoining ground, as such knowledge will be useful in enabling him to make his dispositions with confidence and judgement. Guns should never take up a position directly

in front or in rear of infantry, as by so doing a double object would be presented to the fire of the enemy. Guns should not be posted too soon, but be brought forward at the moment they are required to come into action; previous to this they should be masked either by taking advantage of the irregularities of the ground if such exist, or of any cover that may be near at hand, such as buildings, &c. or when such shelter does not present itself, by placing troops, particularly cavalry, in such a position as will screen the guns from the observation of the enemy. Horse artillery can always do this by means of their mounted gun detachments.

36. Should there be in front, or on the flanks, a sunken road, a wood or village, artillery should be placed so as to be able to direct a fire upon them, that they may not facilitate the approach of the enemy's columns. Guns of position should be stationed so as to command the greatest extent of range in order to profit fully by their superior power. These guns should be protected as much as possible by ditches, abattis, &c. and if there be time, two or three feet of earth may be thrown up in front of them.

Relative  
position of  
artillery in the  
field.

37. Guns are usually placed on the flanks of the troops to which they are attached, for they do not then impede the movements or fire of the latter, but can cross their own fire upon the ground in front. Should, however, the line occupied by the troops be too long to enable the flank batteries to command the whole of the intervening ground, then two or more batteries must be concentrated for this purpose in a central position. As the flanks of a line are in general its weakest points, the guns posted there will require a strong support of cavalry or infantry, and the heaviest pieces should if possible be placed so as to defend these points.

38. If one flank of a line be protected by the nature of the ground, intrenchments, &c. while the other appears in danger of being turned, the greatest number of guns should be posted to the former, so as not to expose a larger number of guns than is unavoidable to the chances of capture. Should the army or division be acting on the offensive, the batteries should be placed in such a position that they may not interfere with the movements of the other troops, and not in such a manner as would unnecessarily draw the fire of the enemy's artillery upon them. No artillery should advance without being properly supported, and the batteries composed of the heavier guns should when practicable second those of lighter calibre; in all circumstances there should if possible be some batteries kept in reserve, troops of horse artillery being well adapted for this purpose, on account of their being able to move with such rapidity.

Employment  
of masses of  
artillery.

39. It is often advisable to concentrate several batteries of artillery into one large battery, and great success has been obtained in various engagements, when such a manoeuvre has been skilfully performed; masses of artillery cannot thus be employed unless they are well disciplined and organized, so great an extent of ground being required for the deployment of a large number of guns. An instance on a small scale of the successful concentration of artillery was given at the battle of Talavera, where three British batteries were formed in a line oblique to some advancing French columns, so that a heavy fire was obtained on the flank of the columns, which were compelled to retire, other more notable instances are given at the end of this Lecture.

Kind of fire,  
and nature of  
projectile to be  
employed in  
the field.

40. The kind of fire and nature of projectile to be employed in the different cases which may present themselves upon the field of battle, depend on a variety of circumstances, such as the nature of the ground, the formation of the enemy's troops, their distance, &c., and the effect that it is desirable to produce.

41. In general, shot and shell are fired against troops *en masse* or in column, or when a line can be enfiladed or taken obliquely; case shot and shrapnel against troops dispersed or scattered, the former being used at short ranges up to about 300 yards, and the latter at the same ranges as those at which shot and shell are fired. When artillery is placed on the prolongation of a line of troops, a single shot may put a large number of men *hors de combat*, and the chance of such a result will make up in a great measure for the uncertainty of striking the object aimed at; there is, however, less chance of failure when the fire is a little oblique, and consequently, this species of fire is more advantageous in action than the former, especially against troops drawn up in line.

Case shot may be employed with advantage against troops at the distance before stated, and especially if there be no great exposure of the gunners to the fire of musketry from the flanks; if troops especially cavalry are advancing upon a battery within a very short distance, double charges of case fired from the guns will do very great execution, and for close quarters smooth-bored pieces would most probably have a great advantage over rifled guns, which cannot fire case; any shell depending upon a fuze is more or less uncertain in its action when the fire is very rapid. The use of case will, however, depend in a measure on the nature of the soil, as it is not nearly so effective on soft or marshy ground, as when the latter is hard and stony.

42. Howitzers are particularly useful in the field when the enemy's troops are covered from the direct fire of the guns by being stationed in hollows, under cover of a wood, or posted

behind rising ground.<sup>1</sup> They are of great service also in the attack of villages, buildings, entrenched posts, &c. as well as against cavalry, as in this latter case, the bursting of the shells frightens the horses, and causes confusion. For the like reason rockets can also be employed with good effect against cavalry.

43. In the different species of fire, it is better to aim a little short of the object than over it, not only on account of the moral effect produced by the shot's ricochet, but also because it is easier to rectify the laying of the piece from observation of the graze,

The choice of  
object.

44. "The choice of the object to be fired at must be determined by the particular purpose the artillery endeavours to effect, and should be changed with that purpose during the course of the action. In the beginning of an engagement, and when the pieces cannot yet contribute to their own defence, they direct their fire where the distance, ground, and position of the enemy hold out the greatest promise of effect. When the battle has advanced, and in decisive moments the objects to be fired at suggest themselves, and the pieces should then fire against those arms of the enemy whose resistance is most obstructive or advance most formidable.

"On the offensive, the fire is chiefly directed against the enemy's artillery, in order to divert their fire from the other troops, and to facilitate the advance of the latter; on the defensive, on the other hand, it is especially directed against the enemy's infantry or cavalry, to prevent their advance.

"In the last case should the artillery be plied by that of the enemy, it should not on that account be induced to divert itself from its object. In an engagement between artillery on either side, it is the most advantageous plan for several pieces to concentrate their fire upon one of the enemy's until it is dismounted, and not to change to another until that object has been effected."<sup>2</sup>

Ammunition should never be wasted on unimportant positions or skirmishes, for the mere sake of creating a few casualties, or when the enemy is at such a distance as to render the fire very uncertain, for by such a course, the ammunition of a battery might be exhausted during the commencement of an action, without producing any adequate results. In general, the fire of artillery should be concentrated as much as possible, as thereby more effect is produced than by a dispersed fire, and it should be remembered that rapidity of fire must always be regulated by certainty of execution.

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<sup>1</sup> Shrapnel or segment shells are of no use against troops posted behind cover, or for setting fire to buildings.

<sup>2</sup> The above excellent remarks are taken from Maxwell's translation of Taubert's small work, "On the use of Field Artillery on service."

45. When a particular point of the enemy's line is to be attacked it is necessary to open fire upon such obstacles as entrenchments, houses, barricades, hedges, &c. which might oppose the advance of the assaulting columns, as well as upon the enemy's artillery, if it be in such a position as to be able to harass the former; and in order to keep up a fire for the greatest length of time, and to avoid incommoding the attacking troops, the batteries should be placed so that their fire will not be in the direction of the roads which will be traversed by them.

Rapidity of  
fire.

46. With well drilled gunners two rounds of shot can be fired from a smooth-bored piece in a minute, the gun being properly laid at each round; three rounds of case can be fired in the same time; shells cannot be fired so rapidly as shot, for however simple the arrangement of the fuze, its regulation will always cause slight delay. When no very great accuracy of fire is required the Armstrong rifled guns can be fired as quickly as smooth-bored pieces.

Movements  
upon the field.

47. The different formations of a battery or brigade of batteries are given in Plate 33, which also shows the extent of ground occupied in each case. In addition to their fire-arms, infantry when in action constantly make use of the bayonet, and cavalry almost invariably use swords or lances; artillery however employs fire alone, and in order to obtain the greatest possible effect, the whole of the guns are in general formed in line; column formations, except for movement, would with artillery lessen necessarily the effect produced. Guns and batteries are sometimes formed *en échelon*, but usually they are deployed when they come within the effective range of the enemy.

Batteries should not leave their positions merely for the sake of slightly diminishing the distance between them and the enemy, as the loss of time occasioned by such a movement would probably not be compensated for, and it should not therefore be undertaken unless some further considerable advantage is presented by the change. Artillery should never be detached with less than two guns, as a single gun is not only very liable to capture, but also in rapid firing, the gun becomes too hot to be efficiently served; with two guns, however, firing alternately, this is not so likely to be the case.

48. When it is advantageous to advance or retire without ceasing fire, the order may be given to do so from either flank of the battery or brigade, by half-batteries or batteries, the remaining guns continuing their fire until the others have taken up their fresh position and are ready to open, when the former in their turn perform the same movement, and so on as required. Should it be desirable to retire slowly, keeping up a fire upon the enemy, the *prolonge* may be made use of, the limbers being



reversed, and ready to move to the rear ; cavalry will hesitate to attack the rear of a column retiring in this manner along a road, or through a defile.

49. Guns should not be abandoned without absolute necessity, as a discharge of canister shot in the face of a charge of cavalry or advance of infantry, might at the last moment, not only check the attacking troops, but also considerably change the aspect of affairs, as regards the fortune of the day. A charge of cavalry may pass through a battery in action, and do but little damage, as the gunners can shelter themselves in a great measure, by getting underneath the guns and carriages ; the drivers can do the same, by dismounting and getting between their horses. At the battle of Balaklava, the English light cavalry rode through one of the Russian batteries, and though cutting down many of the gunners, were eventually obliged to retire, without taking or spiking any of the guns. In this case, however, the Russian artillery was strongly supported by flanking batteries, as well as by both infantry and cavalry. The British gunners behaved in the most admirable manner at Waterloo, for when attacked by masses of cavalry, they served their guns till the last moment, and then retired within the nearest infantry squares for protection, but on the retreat of the French cavalry they issued from their shelter and again served their pieces.

Should it prove absolutely necessary to abandon guns upon the field, care must be taken to render them unserviceable ; this may be done in various ways, viz. by spiking them, by knocking off a trunnion, by breaking the wheels of the carriages, and even by setting fire to the latter. If it appears at all likely that the guns will shortly be recaptured, or that the gunners will only have to retire from them for a short period, they may be rendered unserviceable for the time, by using spring spikes, and by carrying away the side-arms and elevating screws. All repairs which may be required upon the field of battle, should be executed with the utmost promptitude and dispatch, and after an action the whole material of a battery should undergo a searching examination, with regard to the damage which it may have received.

Attack and  
defence of  
positions.

50. Entrenched positions, villages, &c., are constantly occupied by a comparatively weak force in order that it may be able effectually to withstand the attacks of a powerful enemy, which it could not do in the open field. When an army is disputing the advance of an invading force, it usually occupies and intrenches certain positions which are most favorable according to the formation of the ground for defence, and which will therefore give it a great superiority over the invader ; should the defenders be driven from their position, the enemy will nevertheless suffer

much loss in taking them, and his progress will be retarded if not stopped. In the defence of positions artillery play a most important part, great care and skill being required in the disposition of the guns in order that their fire may produce the greatest possible effect.

51. In the defence of a position, artillery should be posted so as to obtain a cross fire on all the approaches to it, and the heaviest guns placed in the most inaccessible positions under the protection of those works which are capable of offering the most prolonged resistance to the enemy's attack, and in such a manner as to be able to keep up a fire on the assaulting columns without incommoding their own troops.

52. The batteries composed of the lightest pieces should be stationed at the most advanced posts, so that they may retire from them with facility, if obliged to do so. Howitzers should be employed for the purpose of shelling the ravines, cross roads, woods, villages, &c. which may be within range, and so prevent their forming a safe shelter for the enemy's riflemen. A large quantity of artillery should be placed to defend those points of the position to which the approach is easiest, but those which appear almost inaccessible should not therefore be left undefended. As before stated, the heaviest guns (or at least a proportion of them) may be posted there. The distances of each battery from different marked objects on the ground in front should be ascertained, in order to insure accuracy of fire.

53. Should the enemy be repulsed, the guns must fire on him so long as he remains within their range, unless by so doing, they would interfere with the movements of troops sent in pursuit. If, however, it is necessary to retire from the position, either temporarily or otherwise, the guns should be withdrawn, according as they may seem in danger of being taken, to such positions as shall have been selected beforehand, in order that they may by their fire arrest or retard the enemy's march.

54. Before attacking an intrenched position, the commanding officer of artillery should accompany the officer charged with the execution of such operation, in order to make a reconnaissance of the roads which lead to the position, the nature of the works to be attacked, as well as that of the surrounding country, with the view of placing his guns in the most favorable and commanding situations.

55. In the attack of works in the field, the guns should be placed in the prolongation of the faces in order to enfilade them, and to destroy their accessory defences, such as traverses, &c.

Howitzers, from the nature and size of their projectiles, should be used particularly for this service. The guns of the largest calibre which accompany the attacking force, should be placed at such ranges as fully command the position, in order to fire not only upon the intrenchments, but also on the troops in rear, if the works be supported.

56. The artillery open and continue their fire, while the attacking columns march to the assault in the direction of the capitals of the salients, and then take up such fresh positions as to be able either to support the infantry in case of a repulse or of a counter attack, or if successful to follow these troops when the works are carried.

57. Good instances of the attack of intrenched positions were given at the battle of Borodino, in 1812, when the Russians so obstinately defended themselves against the French ; at the taking of Warsaw by the Russians in 1831, which latter is cited by Okouneff as an example of what immense results can be accomplished by the concentrated and well sustained fire of an enormous battery of 100 guns or more ; 120 is the number he gives at Warsaw, but the Polish account states that there were 200 guns. It is worthy of remark that, at the taking of Warsaw, the light pieces advanced with the assaulting columns in order by the fire of canister to keep the defenders from the parapets ; this was also done in the most gallant way by a battery of French Horse Artillery at the taking of the Malakoff at Sebastopol, but the enemy's heavier guns not being silenced the battery was almost entirely destroyed.

Fig. 1, Plate 35, taken from the secret strategical instructions of Frederick the Great is given in that work as an instance of an unattackable position ; the batteries are so disposed as to concentrate their fire upon an advancing enemy whose front would necessarily be narrowed by the formation of the ground. Instances of the successful application of entrenched positions were given by Frederick the Great at Bunzelwitz in 1761, and by the Duke of Wellington who constructed the celebrated lines of Torres Vedras.

58. The rules which should be observed in the employment of artillery for attacking or defending an intrenched position, would also apply to the attack or defence of a village.

Passage of a  
river.

59. When a *corps d'armée* or division is about to cross a river in the face of an enemy, the guns should be disposed so as to command the space which the enemy would occupy to oppose the passage and formation of the troops upon the opposite bank, the employment of artillery is indispensable to enable them to

effect this object. The batteries should be disposed as in Fig. 2, Plate 35, so that their fire may cross on the opposite bank, and thus protect the deployment of the troops after crossing; in order that the guns may do this most effectually, the ground upon which they are placed should command that on the opposite side of the river, the covering batteries do not cross until after the rest of the troops.

60. In the defence of the passage of a river, the heaviest guns should be posted so as to command the bridges, fords, and the approaches thereto, and to take in flank any troops which may have already crossed the river. The other guns should be placed so that they may be able to concentrate their fire upon the main body of an approaching enemy. In the defence of a *tête de pont*, two batteries (*a* and *b*) should be posted as in Fig. 3, Plate 35, so as to play upon the advancing troops, and a third battery should be placed directly in rear of the bridge, in order to prevent its use or repair by the enemy after the work has been taken.

61. The passage of the river Lech, in 1632,<sup>1</sup> by Gustavus Adolphus of Sweden (see Plate 36), is perhaps as remarkable an instance as can be given of the passage of a river in the face of an enemy strongly posted and entrenched. The imperial army under Tilly, occupied the opposite bank to the Swedes, and the ground on which it was posted rose gradually to the rear, where stood a large wood of thorn bushes and shrubs. About half way between this wood and the head of the river ran a small brook in the form of a crescent, in front of the apex of which, Tilly had placed two considerable bodies of infantry (*DD*), strongly entrenched. Upon the inner bank of this brook, and directly in rear of the infantry, were stationed a number of guns of large calibre (*CC*), while behind the latter was placed the principal camp of Tilly, with a force of 8000 men (*AA*). The rest of the infantry was disposed with much judgment; and the cavalry of the imperial army, like that of the Swedes, was posted in rear of the wings, with the exception of two divisions (*EE*), who had taken up such a position as to be out of the range of the Swedish artillery. Contrary to the advice of his generals, Gustavus determined to force the passage of the river, and accordingly towards night fall, embarked in small boats a detachment of Finlanders, accompanied by 200 pioneers, and some engineers. These crossed the river under the protection of some powerful batteries that the king had placed in the middle, and at the extremities of the bend formed

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<sup>1</sup> Extracted from M. de Grewenitz's *Treatise on the Organisation and Tactics of Artillery*.

by the Lech. The smoke and fire of these batteries masked the operation. As soon as this force had crossed the river, it threw up a *tête de pont* to protect the bridge, the construction of which had been commenced, from any fire either direct or oblique, which Tilly might bring to bear on it. The break of day revealed to the imperial general this most extraordinary and daring undertaking, who, though at once recognising the impossibility of arresting the passage of the river by the Swedes, for the reason that their artillery commanded and kept up a constant fire upon the opposite bank, at first attempted to direct two batteries (*GG*) against the bridge, but they produced no effect, less even on account of the *epaulement* which the Swedes had thrown up, than on the nature of the ground, which on one side was low and marshy, and on the other thickly covered with wood. The inutility of this attempt, made Tilly determined to act only on the defensive, and he accordingly set all his available men to work in increasing the profile of his entrenchments, and in constructing abattis, &c.; but the noise of the axes and saws having betrayed his projects, Gustavus directed a heavy fire upon the forest in which the imperialists were at work. In the mean time the bridge had been completed, and the king, after having first reinforced the troops which were already on the opposite side, caused the main body of his army, ranged in the order of battle, to cross the river. Previous to this he had placed large corps of infantry (*KK*) between the batteries on the bank of the river, and covered them with an entrenchment. In vain did Tilly employ the *élite* of his troops to prevent the passage of the Swedes and their deployment after crossing, in vain did his Master-General of the ordnance charge them with impetuosity, he was repulsed by the artillery of Gustavus, and struck down by a cannon shot, at the moment in which he was about to make a fresh attempt. To repair this check, Tilly descended from the wood at the head of the old and tried Burgundians. The sight of this old general, covered with scars and conqueror of thirty-six battles, redoubled the ardour of his troops, but twenty minutes afterwards he was struck in the knee by a shot, and his fall put an end to all further resistance. The disorder of the imperial army was also augmented by the advance of two large corps of Finnish cavalry (*LL*) who, in their eagerness to engage, had crossed the river by swimming. Thus was accomplished the passage of the Lech, rendered chiefly remarkable by the judicious manner in which Gustavus and his general of artillery Torstenson, employed that arm. Both armies were of about equal strength, the imperialists having 70 and the Swedes 72 pieces of ordnance, but the effects of the fire

of the former were almost nullified by the woods and marshes on the banks of the river; while the projectiles of the latter passing over these obstacles, at the first graze reached and did great execution among the enemy's infantry and artillery.

Embarkation  
of field  
artillery.

62. In embarking artillery in the presence of an enemy, or when the latter is close at hand, the officer commanding should endeavour to embark as much of his charge as possible at the earliest period, and with the utmost dispatch. He must however remember, that the possibility or probability of having to leave some guns, should not interfere with the more important consideration of keeping on shore a sufficient force of artillery, to repel any attack which may be made.

63. The horses and carriages should first be embarked, with the exception of such a proportion of guns and limbers as is calculated for the defence of the position, which the other troops may be occupying; if this be near the water, the limbers may also be sent off, and the guns dragged to the boats by men. A sufficient supply of ammunition should be at hand in a boat or two, close to the shore.<sup>1</sup> If the position be a mile or two from the place of embarkation, it may be necessary to retain a certain proportion of horses. In all cases, the guns are embarked the last, and should the enemy be actually present, the embarkation of the last of the troops generally takes place at night.

Disembarkation  
of field  
artillery.

64. In disembarking, the artillery should endeavour to gain the shore and land with the other troops, whose object is to cover the landing of the main body; a sufficient supply of artillery ammunition and stores should be in boats near the shore. If on a coast, the landing is generally covered by the smaller steamers, also by boats filled with guns and howitzers.

In disembarking guns from boats, they should be run on shore muzzle foremost, so as to be ready for action immediately; this operation should not at the most take longer than five minutes, provided the water be tolerably smooth.

65. No absolute rules can be laid down for the application of artillery in the field under all the different circumstances that may arise, but the previous remarks which are based upon the experience of numerous wars will no doubt be of much use to an artillery officer; and in order to increase the interest on this

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<sup>1</sup> Field Battery Exercise.

subject, accounts of a few engagements in which artillery was judiciously and skilfully handled are here given.<sup>1</sup>

*Battle of Friedland.*

66. This battle was fought on the 14th June, 1807, between the French and Russian armies, and terminated in favor of the former, a result mainly attributable to the admirable handling of their artillery and the concentration of its fire. The French advanced guard under Marshal Lannes, having on the 13th June arrived at Posthenen, about three miles from Friedland, Benningsen, who commanded the Russians determined to attack it before the arrival of other corps. Mortier arriving however shortly after the Russian general's attack (on the 14th), the latter meeting with so much resistance, passed his whole army over the river Alle, and deployed it into two lines in an extended position (See Plate 37, *AB*) having the town of Friedland and the river Alle in its rear. The French by alternate attacks between Friedland and Posthenen sustained the conflict alone until five o'clock in the afternoon, when the rest of the French army arrived upon the field, united itself with the above corps, and formed a fresh order of battle under Napoleon himself; Ney's division being on the right, Lannes in the centre, and Mortier on the left. The corps of General Victor, and the troops of the imperial guard, formed the reserve. Ney's column advancing from the woods behind Posthenen drove in the Russian left and supported by a battery of thirty guns placed 400 paces in advance of the centre of the line prepared to storm the town, obtain possession of the bridges, and thus complete the ruin of the enemy. Ney in wheeling to attack the town was assailed in flank by some Russian batteries on the opposite bank of the Alle, and being charged by the Russian imperial guard he was repulsed, the artillery causing frightful ravages in his ranks. Ney's corps soon however returned to the charge, assisted by a battery of thirty-six pieces placed on its right, which were collected from different divisions by Senarmont who commanded the French artillery; this concentration of the divisional artillery was contrary to the wishes of the generals, but was done with Victor's consent. This large battery opened at 400 paces, then advanced after a few rounds to 200, and again to 120, silencing the Russian batteries on the right bank, and driving the infantry into the defile before Friedland. The Russian cavalry attempted to check the advance of the battery, but Senarmont promptly changed front and repulsed it with ease. Napoleon himself was astonished at the effect produced by this

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<sup>1</sup> These accounts are not taken from any single work but from several, in order by comparing them to obtain a more accurate description,

battery, acting thus independently. The town was stormed, and the bridges set on fire, the retreat of the Russian right being thus cut off; it succeeded however in crossing by a ford higher up; the defeat of the Russians was complete, and their loss severe.

*Observations.*

The position of the Russian batteries on the right bank was good, and the guns would probably have succeeded in protecting the Russian left flank, had it not been for Senarmont's unexpected and overwhelming manœuvre. In order to accomplish the latter, the French artillery must have been in a high state of efficiency and discipline. The necessity of a reserve artillery is here seen, for had there been a strong reserve the divisional guns need not have been taken from the troops to which they were attached.

*Battle of Wagram.*

67. In this battle, the use and application of artillery is shewn very conspicuously, both as regards its employment upon the field of battle, and also with respect to its utility in covering the passage of a river. In order to enable them to cross to the left bank of the river, the French had placed powerful batteries upon different islands, see Plate 38, *a, b, c, d*, situated between that of Lobau (across which it had been determined to force the passage) and the opposite bank, consisting in the aggregate of twenty-eight mortars and sixty-two guns, making in all ninety pieces of ordnance. This judicious disposition of their artillery enabled the French to construct their bridges during the daytime; and when the Austrians attempted to take advantage of the French troops being shut up, as it were, in the island of Lobau, by opening fire on them from their guns, which were posted near the Danube, a general cannonade was commenced by all the batteries (*a, b, c, d*), which in a short time silenced that of the enemy's artillery, and set fire to the little town of Enzersdorf, thus depriving the Austrians of an important point of support. The bridges having been finished, the passage of the river was accomplished on the 5th and 6th June, 1809, the latter being also the day on which this memorable battle took place.

At the commencement of the action, the right wing of the Austrian army (*AA*), which had as yet met with no check in the skirmishes which had taken place on the passage of the river, advanced between Breitenlee and Gros-Aspern, driving back the French left (*BB*) behind Esling and Enzersdorf, while on the other hand, the right wing of the latter army (*CC*) was attempting to turn the left of the Austrians, and to conceal this manœuvre by attacks on Glinendorf and Markgraf-Neusiedel (*DD*). The reserve of the French, composed of infantry and artillery placed near Raschdorf, awaited the issue of these combats, in which



the guns posted in line kept up a brisk cannonade from both sides. Up to this point the victory remained undecided, the right wing of the Austrians was already priding itself, as at Marengo, on having gained the day, when the corps of Davoust and Oudinot succeeded in turning the left wing. Their artillery (*EE*), covered by a cloud of riflemen commenced a fire so rapid and well-directed, that almost all the Austrian guns on that flank were dismounted, and the position between Wagram and Markgrafen-Neusiedel thoroughly enfiladed. At the same time, the famous artillery attack against Adlerka was ordered by Napoleon, who sent General Lauriston with 100 guns from the reserve to take up a position in front of the corps of Marshal Massena. This formidable battery (*FF*) advanced at a trot, until within a short distance of the enemy, and then poured death and devastation among his ranks; while protected by this artillery the attacking columns marched upon Adlerka. The result of the day did not remain much longer doubtful, although the Prince of Leichtenstein attempted for some minutes to defer the decisive blow near Adlerka. The Austrians retreated in perfect order, being pursued by artillery alone, which nevertheless inflicted considerable loss upon them.

**Observations.** Okouneff, in criticising this artillery manœuvre, observes that it failed to effect what it was doubtless intended to accomplish, viz. to break the Austrian centre, and the reasons he gives for its want of complete success are, (1) that it opened at too great a range and remained stationary instead of advancing, (2) that the fire was not kept up for a sufficient length of time, as the Austrian artillery was not by any means silenced or their infantry broken, and (3) that the attacking columns were formed in an unsuitable manner.

Taubert gives the above manœuvre as a magnificent example of the employment of artillery in masses, but as a less successful one than that at Friedland. He says, "To the fire of this enormous battery, which continued for half an hour, succeeded the attack of imposing masses of cavalry and infantry; but they threw themselves upon troops completely unbroken, and were repulsed. Before the formation of fresh reserves was completed to renew the attack, the Austrian commander-in-chief was induced, in consequence of the occurrences on his left wing to commence the retreat; so that it may be said with perfect truth, that the great attack against the Austrian centre did not decide the day, but that the turning attack under Davoust did."

#### *Battle of Lutzen.*

68. The battle of Lutzen was fought on the 2nd May, 1813, between the Allies and the French, ending in the retreat of the former, and was the first action in which the Prussian artillery

was engaged subsequent to the abolition of the battalion guns, and consequent establishment of distinct batteries and brigades. The allies had 439 guns while the French had but 236, so that the victory on the side of the latter may be considered to be due to the perfect knowledge possessed by Napoleon of the application of artillery in the field, and especially as regarded the employment of the reserves. The first position of the Prussians is marked in Plate 39 by the letters *AA*, that of the Russians who followed in reserve by *BB*. The Prussian brigade of General Klüx, with its artillery, commenced the action near Gros-Görschen, and was followed in succession by the others. In this manner the combat was sustained with varied success at Gros-Görschen, Klein-Görschen, Rhana, and Kaya, from half-past eleven in the morning until late in the afternoon, by which time the Prussian artillery had expended a great portion of its ammunition. The numerous artillery of the Russians relieved a portion of that of the Prussians, and likewise expended its ammunition by a dispersed and scattered fire, and in place of a powerful reserve of guns, which the Russians should have posted out of range of those of the enemy, to be used for striking a decisive blow when necessary, the ardent bravery of these troops carried them all forward, one after the other, until they found themselves actually engaged. At six o'clock p.m. the Prussians attempted, by redoubling their efforts, to retake the four villages above named, and their reserves were already in action when the last of the Russian troops arrived upon the field. This moment was decisive. A Prussian field battery engaged in a brilliant combat between Rhana and Kaya, and without being deterred by the numerous artillery in its front, sought to gain the heights which gradually sloped up from the valley, and crushed the French masses within range with canister. It succeeded in unlimbering, even when within musket range of the enemy. It was at this point that the fortune of the day was decided; if, instead of five guns, there had been half of those of the Russian reserves, the battle would have been gained by the allies. When the Russians and Prussians were in possession of the villages, and had taken up the position *CCC*, Napoleon was aware that the decisive moment had arrived, he therefore brought up his reserve of Imperial Guards which had not yet been engaged; sixteen battalions advanced in close column *DD*, preceded by eighty pieces of artillery under Drouet, and followed by the reserve cavalry. The allies, already weakened, offered but little resistance, and were driven out of Kaya and the other villages except Gros-Görschen, which they retained till night. The allies retreated in the night in consequence of the arrival of Beuharnois on their right flank late in the day, Bertrand also advancing on their left.

**Observations.** The allied army employed in this engagement an immense number of guns, nearly seven to 1000 men, but instead of keeping a strong reserve ready to act with effect upon an emergency, they appear to have placed their batteries between the infantry columns, and allowed them to scatter their fire. Fifty pieces were however in position at Lisdorf, and if brought up to oppose the last French attack on Kaya, the battle ought to have been gained by the allies, notwithstanding the preponderance of the French numbers. As has been remarked in Article 10 of this Lecture, the French base their amount of ammunition for field service upon the results of the battle of Lutzen.

#### *Battle of Hanau.*

69. After his defeat at Leipsic, Napoleon was retreating from Erfurth on the Rhine, when Marshal Wrede with about 48,000 men took up a position at Hanau to intercept him. The allied army was posted in front of Hanau, its right resting on the Kenzig, the left on the road from Erfurth to Frankfort, and sixty guns were placed in the centre to prevent the French from debouching from the forest of Hanau, which was occupied by light troops to harass the enemy's flanks (Plate 40). Napoleon's force amounted to 80,000 men, but 30,000 were completely disorganized; he had however 200 guns, most of them belonging to the artillery of the guard, which were still in a very efficient state, and commanded by the celebrated General Drouet.

At eleven o'clock a.m. on the 30th October, 1813, the French columns advanced, and after hard fighting drove the allies out of the wood, but when they attempted to deploy on the plain beyond, the fire from the allied guns completely overwhelmed them, and prevented any further advance. After some hours ineffectual fighting, General Drouet proposed to the Emperor to force a passage with his guns; Napoleon acceding, he brought forward fifteen guns, three of which he placed upon the road, and the other twelve to the left upon the border of the wood, the guns being supported by two battalions of chasseurs. These pieces had at first to sustain the concentrated fire from the enemy's large battery, but were admirably served, and gradually reinforced by other guns being pushed forward, until at last some heavy 12-prs. were deployed to the right of the road in such a manner as to take the allied guns obliquely and to establish a decided superiority of fire. Wrede's troops now suffering much from the fire of the French guns, he advanced his cavalry to charge them, but the French gunners, waiting till the cavalry were within fifty or sixty paces, poured in a general discharge of case which threw it into confusion, its rout being completed by the French cavalry. The French artillery supported

by its victorious cavalry now advanced 200 toises and took the allied centre obliquely. At eight p.m. Wrede seeing his army in disorder withdrew his troops.

**Observations.** The French artillery of the guard was brought to great perfection by General Drouet, this battle affording an instance of its wonderful steadiness in deploying under a murderous fire, and of the admirable service of the guns at first posted against overwhelming numbers, as also of the skilful disposition of the pieces by Drouet. An example is also afforded by the early part of the action of the helplessness of an army without its artillery, when opposed by an inferior force with artillery strongly posted.

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ORGANIZATION, EQUIPMENT, AND APPLICATION OF

ARTILLERY.

[Continued].

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*Siege Artillery.*

General  
remarks.

1. THE objects and equipments of siege artillery are very different from those of artillery for service in the field, the quantity and variety of the matériel required being very much greater, as well as the time necessary for its collection. The organization of artillery for siege purposes, is, however, in some degree simpler than that of field artillery, as there is generally a surer basis on which to ground such organization.

2. Sieges, from the great expense and trouble attendant upon them, should not be undertaken, unless by such a course the enemy may either be much crippled in his resources or deprived of his points of support ; or that the capture of any particular fortress is absolutely necessary for the reduction of a country, and is likely to produce a considerable moral effect.

Objects of siege  
artillery.

3. The purposes for which artillery is employed in sieges, may be enumerated as follows :—

(1) To keep down the fire of the besieged, and protect the besieger's works, thus enabling him to make his approaches to the fortress with greater facility.

(2) To defend the batteries and parallels against sorties, &c.

(3) To drive from their lodgments any troops which may hinder the progress of the parallels or batteries, by harassing the working parties, and guards of the trenches.

(4) To ruin the defences of the besieged, and to prevent his repairing the damages which they may have received.

(5) To destroy the enemy's stores and magazines.

(6) To form such breaches in the revetments as may be necessary to admit the assaulting columns ; and

(7) To cover and support the movements of the assaulting columns on the day of attack.

From the above remarks it will be seen what an important part artillery has to perform, in all the principal operations of a siege, and that therefore the matériel of a siege train must be as complete, and its organization as perfect as possible.

Organisation  
of siege artil-  
lery.  
Principles on  
which based.

4. The principles which regulate the organization of a siege equipment, are based not only on the plan and probable number of guns in the place to be attacked, but also on the state of the fortress, and of its armament at the period of the siege, as well as on the strength of the garrison which defend it. The foregoing having been ascertained, approximately at least, the chief points to be decided are the nature and quantity of ordnance required for the siege, and the proportion of ammunition which the length of its duration is likely to demand.

Description of  
ordnance for  
siege purposes.

5. No precise rule can be laid down with regard to the description of ordnance best suited for a siege equipment, as this must be determined to a great extent by the facility of transport afforded by the country in which the operations are to be carried on, and by the nature of the works to be attacked. Guns and mortars of the largest calibre were employed at the siege of Sebastopol; but this remarkable siege can only be taken as a special case, our immense resources as regards ordnance and other war matériel being mainly attributable to the abundance of water transport, and to the proximity and active co-operation of a large and powerful fleet.

6. Previous to the Crimean war, the 24-pr. gun of 50 cwt., the 10 and 8-inch howitzers, the 10 and 8-inch iron mortars, and the 5½ and 4½-inch brass mortars, were considered the best descriptions of ordnance for siege purposes; but it is probable that in any future siege which may be undertaken by us (prior to the adoption of rifled siege guns), the 32-pr. gun of 50 cwt. will be substituted for the 24-pr., and the 8-inch shell gun for the two species of howitzers, as the much greater range and precision (of the shell gun) would more than compensate for the difference between the size of the projectile thrown by it, and by the 10-inch howitzer.<sup>1</sup> The 32-pr. and 8-inch gun were employed in the Crimea.

7. The French have hitherto chiefly used 24-prs. and 16-prs. (brass) as their principal siege guns. The introduction of rifled ordnance would, there is no doubt, cause a considerable revolution, not only in field but also in siege operations; at all events as regards the nature of guns employed. The projectiles employed in a siege may be enumerated as follows:—round and hollow shot; common and shrapnel shells; grape, canister, and pound shot; together with carcasses, light balls, and rockets.

Quantity of  
ordnance.

8. The quantity of ordnance necessary for a siege must be in a measure determined by various circumstances which have

<sup>1</sup> Although field pieces do not form part of the regular equipment of a siege train, they may be found very useful in the defence of the advanced trenches, and in places where it would be difficult to move guns of larger calibre. Several were made use of in this way at the siege of Sebastopol.

been already mentioned, such as the extent of the works, armament of the fortress to be attacked, &c. ; though experience has shewn that on many occasions the number of guns employed depended rather upon expediency, and the resources of the besieging army at the time, than upon any fixed rule. Different numbers have been chosen at various times as the bases for siege operations, and the following table taken from the *Aide Memoire à l'usage des Officiers d'Artillerie*, will show what have been the views of some of the principal writers on artillery with regard to this subject.

As proposed by	No. of Pieces.	In the proportion of, per 100.			
		Guns.	Howitzers.	Mortars.	Pierriers.
Vauban .....	160	70	...	15	15
Bousmard.....	168	50	18	22	10
Durtubie .....	207	62	12	18	8
Dupuget .....	200	65	12	18	6
Gassendi .....	160	62	15	15	8
Austrian Equipment .....	178	45	13	35	7
Prussian Equipment .....	142	60	15	20	5

9. In 1819, a Committee of artillery officers proposed 100 pieces as the basis for all future siege equipments in the proportion of 60 guns, 15 howitzers, and 25 mortars ; and subsequently 40 small brass mortars were added to the above. This basis was to be considered as a maximum, and was to be divided or subdivided according as the fortress to be attacked was of the second, third, or fourth class. Sir John Jones proposed as a maximum 106 pieces, to consist of 40 24-prs., 20 18-prs., or heavy howitzers, and 46 mortars. It was however afterwards thought that 30 pieces of heavy ordnance, with a proportion of brass mortars, should be considered as the minimum basis for a siege equipment, for it would be more convenient to multiply this quantity, than to subdivide the larger one, which besides is hardly adequate as a maximum basis.

Relative proportions of the different natures of ordnance.

10. As a general rule, it may be stated that the different natures of ordnance for a siege should be about in the following proportions, viz. :—

Guns .....  $\frac{4}{9}$   
Howitzers, or shell guns .....  $\frac{2}{9}$   
Mortars .....  $\frac{3}{9}$

besides a certain number of small brass mortars. The relative proportions of shot and shell guns, or howitzers and mortars, however, must depend on the nature of the works to be attacked ; against masonry it is necessary to employ solid shot ; shells, on the contrary, should be used against earth-works, and if it be intended to bombard a town or arsenal, the proportion of mortars must be increased. The French artillery,

*Aide Memoire* (Edition of 1856), gives the following as a siege equipment :—

24-pr. guns .....	40
16-pr. ditto .....	40
8½-inch howitzers (22 c) .....	40
10½-inch mortars (27 c) .....	20
8½-inch „ (22 c) .....	20
6-inch „ (15 c) .....	15
Total.....	175

British  
ordnance at  
the siege of  
Sebastopol.

11. Four battering trains were sent from England, and employed at the siege of Sebastopol in 1854 and 1855.

*Battering Trains sent to the East.*

	24-pr. guns 50 cwt.	32-pr. guns 50 cwt.	8-in. guns 52 cwt.	10-in. mortars, L.S.	8-in. mortars.	6½-in. mortars.	Lancaster guns.	Total.
1st Siege Train ...	15	...	10	5	...	10	...	40
2nd do ...	15	...	10	5	...	10	...	40
3rd do ...	...	20	10	10	...	10	...	50
4th do ...	...	20	15	...	10	...	3	48

10-in guns, 68-prs., and 32-prs. were also procured from the fleet at different periods of the siege, as well as 13-in. and 8-in. mortars from Malta.

In addition to the foregoing, 192 24-pr. and 12-pr. rockets, in equal proportions, were likewise supplied.

The following table will shew the description and number of ordnance used by the English at the siege of Sebastopol, and the armament of their batteries at the commencement of each bombardment.

Bombardments.	Mortars.				Guns.							Total.
	13-in.	10-in.	8-in.	5½-in.	Lancaster.	63-pr.	32-pr.	24-pr.	9-pr.	10-in.	8-in.	
1st—Oct. 17, 1854	...	10	...	...	4	5	7	30	...	...	16	72
2nd—Apr. 9, 1855	20	16	...	...	...	6	42	20	...	4	15	123
3rd—June 6, 1855	26	17	...	...	...	8	49	...	...	8	46	154
4th—June 17, 1855	30	17	8	...	...	8	49	...	...	8	46	166
5th—Aug. 17, 1855	33	24	7	20	1	4	53	...	...	8	46	196
6th—Sept. 8, 1855	34	27	10	20	2	6	61	...	3	7	37	207

The total number of ordnance employed by us at this extraordinary siege, from its commencement in October, 1854, to its close in September, 1855, was 367, and to this must be added, 1352 pieces used by the French, making altogether 1756 pieces of all calibres; the English guns were however of much heavier



metal than those of the French.<sup>1</sup> These numbers are quoted merely as matters of history, and not as a basis whereon to found any future siege equipment.

Proportion of  
ammunition.

12. The nature and number of ordnance for a battering train having been determined, it is desirable to fix in some measure the amount of ammunition that may be required though this quantity, depending as it does upon the duration of the siege and on the vigour of the defence, must of course be very variable; it may, however, be stated that the number of rounds for each piece of ordnance should not exceed that which is calculated to render it unserviceable. Fifteen hundred rounds per gun, exclusive of case, shrapnel, and carcasses, is the utmost limit which has been assigned to iron ordnance; but this large proportion would not be required in the ordinary attack of fortresses of the second or third class, and might therefore be reduced to what was considered sufficient in the latter cases. In many of the Peninsular sieges, even in the case of the most vigorous resistance, a much less proportion was made use of, not exceeding in some instances 500 rounds per piece of ordnance, but this was mainly attributable to the want of transport and limited time; the latter often requiring that the assault should take place as early as possible. It has been thought that for iron mortars and howitzers 500 rounds, besides carcasses and shrapnels, might be fixed as a sufficient proportion for the attack of a fortress of the first class, but this as before stated, must depend upon the nature and length of the siege.

13. It is difficult to decide the ratio which shrapnel, case, carcasses, &c. should bear to the quantity of round shot and common shell, circumstances can alone determine these. At the siege of Sebastopol, they bore in the aggregate the proportion of from one-tenth to one-twelfth.

The following proportions of the different species of projectiles would be a fair quantity for a battering train of 100 pieces :—

	Round shot.	Hollow shot.	Common shell.	Shrapnel.	Grape or canister.	Pound shot (rounds).	Carcasses.	Total.
32-pr. gun .....	1000	...	100	50	50	...	...	1200
24-pr. gun .....	1000	...	...	50	50	...	...	1100
8-in. gun .....	...	200	600	50	50	...	...	900
10-in. mortar .....	...	...	600	...	...	50	10	660
5½ or 4½-in. mortar...	...	...	300	...	...	...	...	300

Quantity of  
powder.

14. As to the proportion of powder required for a siege train, it is determined not only by the number of rounds per

<sup>1</sup> The French siege guns consisted of 24, 16, and 12-pr. guns, and of howitzers of 22, 16, and 12 centimètres, all of which were of bronze. They obtained some heavier pieces from their ships, viz. 50 and 30-pr. guns, and some heavy shell guns.

gun, but also by the charges employed, and varies according as these are intended for direct or ricochet fire. There should therefore be a number of extra barrels of powder provided above that which may have been calculated as adequate to the quantity of projectiles required, in order to allow of increase in the charges for the different natures of ordnance.

Ammunition at the siege of Sebastopol.

15. As the siege of Sebastopol is certainly the most remarkable which has taken place in this age, details and tables of the proportion of ammunition issued and expended by the English during its progress, are here subjoined.<sup>1</sup>

Expenditure of Ammunition (Naval Brigade included) during the Siege of Sebastopol.

Bombardments commenced.	Mortars.				Guns.							Total.
	13-in.	10-in.	8-in.	5½-in.	Lancaster.	24-pr.	32-pr.	6-in.	10-in.	68-pr.	9-pr.	
October 17, 1854 .....	...	2745	...	...	370	7112	5711	5043	...	...	...	21881
April 9, 1855 .....	5519	4922	...	...	...	8679	5539	1604	640	3730	...	30633
June 6 " .....	5271	5543	...	...	...	...	5627	12300	1142	...	...	32883
June 17 " .....	2266	884	...	...	...	...	9746	6712	1706	1350	...	22684
Aug. 17 " .....	5976	5267	...	906	...	...	6984	6500	492	145	...	26270
Sept. 8 " .....	6677	4860	870	314	...	...	9894	4111	254	1466	...	28476
Expended at other times	10607	13122	2304	3627	1172	12713	22375	20161	1877	...	682	88640
Carcasses and light balls	...	...	...	...	...	...	...	...	...	...	...	405
Total .....	39336	37343	3174	4827	1542	28504	65876	67331	6111	6721	682	251872

In addition to the ammunition, laboratory, and other stores, including shot furnaces,—gyns, &c. must be furnished in ample proportions for the service of the ordnance during a siege.

Ammunition supplied with First Battering Train.

		8-in.	24-pr.	10-in.	5½-in.	Total.
Shot	Hollow, 48 lbs. ....	2000				2000
	Round .....		7500			7500
	Common case .....	250	375			625
Shell	Pound, rounds (100 each) ...			125		125
	Common .....	3000		1500	1000	5500
	Shrapnel .....	300	300			600
	Carcasses .....			25		25
Total rounds .....		5450	8175	1650	1000	16375

The ammunition for the 2nd battering train was similar to the above, and included besides a reserve for both trains, consisting of 250 rounds per gun and per 10-in. mortar, and of 100 rounds per 5½-in. mortar. For the 3rd battering train, 1100 to 1200 rounds per gun, 760 rounds per 10-in. mortar, and 200 for each small mortar, was supplied. The 4th battering train was furnished with 1015 rounds per gun, 900 per mortar, and 300 per Lancaster gun.

<sup>1</sup> The projectiles supplied to the French Siege Batteries amounted to 1,159,390 these include 75,000 hand grenades.

Gun carriages  
and mortar  
beds.

16. Each gun is provided with its carriage, and each mortar with its bed ; there should be also a certain number of spare gun carriages to replace those which may become unserviceable. The French fix the proportion at  $\frac{1}{3}$  for the heavier guns and mortars, and at  $\frac{1}{4}$  for the lighter pieces ; it has not however been the custom in the British Service to allow so large a proportion as this. The Committee in 1819, proposed in their estimate of a battering train, one-tenth as a sufficient number of spare gun carriages, and no allowance was made for the destruction of mortar beds.

Transport  
carriages.

17. Besides the siege or travelling carriages, sling and platform wagons must be provided for the transport of guns and mortars, as well as Flanders wagons, trench, and hand carts for that of ammunition and other stores. Sling wagons are very useful in moving guns, when it is required to replace those that are injured, or when guns provided with garrison or naval carriages are used, in which case the carriage is also transported upon the wagon. At Sebastopol, the number allotted per train was only two ; the Committee, however, recommend one per ten pieces of ordnance. Platform wagons are used chiefly for carrying mortars and their beds, though they may also be employed for carrying guns ; the sling wagon is however preferable for this purpose. Flanders wagons with trench and hand carts are intended principally for the transport of ammunition and stores, the two latter being for the most part designed for conveying shot, shell, &c. from the park to the trenches. There should be an ample allowance of these three species of carriages.

*Carriages supplied with First Siege Train, Siege of Sebastopol.*

Travelling carriages for 8-in. gun . . . .	10
do 24-pr. . . . .	15
Flanders wagons . . . . .	6
Store do . . . . .	6
Sling do . . . . .	2
Forge do . . . . .	3
Platform do . . . . .	5
Hand carts . . . . .	15
Trench do . . . . .	15
Large drag . . . . .	1
Small do . . . . .	2
Total . . . . .	80

A quantity of man harness ought to be supplied with every siege equipment, for a considerable part of the transport of shot and shell, and sometimes even of ordnance, may have to be performed by men. In the Crimea, a number of the limbers belonging to the horse artillery and field batteries were fitted

up for carrying shot, by having the ammunition boxes removed, and battens nailed round the body of the limber so as to form a sort of open box.

**Platforms.** 18. The platforms at present in use in our service for siege purposes are of three kinds, viz. the Madras, Alderson's, and Clerk's platforms; the first are generally used for guns, the second for mortars, the chief disadvantage of the first kind being that they contract the lateral range of the gun and are traversed only with the greatest difficulty; they are however quickly laid if the ground be favorable. In addition to the number of platforms equal to that of the pieces of ordnance in a siege train, a quantity of materials should be furnished for repairing and keeping the same in order. These three platforms have been already described in Lecture V.

**Gyns.** 19. Triangle gyns are included in all siege trains, and are used for mounting guns and mortars in the batteries; there should be a sufficient number to allow one at least to each battery, or line of batteries, besides those used in the service of the depôts and parks; about one for every twelve pieces of ordnance in a train would be a fair allowance.

**Transport.** 20. The great quantity of ordnance and matériel for the siege of a considerable fortress requires that large and efficient means of transport should be provided, as the want of such has often rendered sieges impossible or ineffectual. A certain proportion of the transport of a besieging army should be allotted for the battering train, and in our service, it is probable that the Military Train would have to perform a great portion of the duty of conveying guns and stores to the parks and batteries; but the field batteries and horse artillery must also (as was the case at Sebastopol) be prepared to furnish a certain number of horses for the service of the siege train. It is impossible to calculate the number of horses required for this service, as so much depends upon the resources found in the country where the operations are to be carried on. In a train of 100 pieces, 160 horses per piece has been given as an average, but this seems a very high estimate, and it is but seldom that so large a number of horses as 16,000 could be procured or spared for this purpose. With regard to water transport no difficulty exists in the case of a maritime power like Great Britain, which has at its command so numerous a navy, both of ships of war, and merchant vessels.

**Number of men.** 21. The number of men required for a siege equipment is based upon what is sufficient to allow of three full reliefs, exclusive of laboratory duties, conductors of stores, a reserve to replace casualties, &c., &c. It has been calculated that about

twelve men per piece of ordnance should be able to fulfil these conditions, if it be taken for granted that the whole number of guns would not be brought into play at the same time. With a train composed solely of 32-pr. guns, 8-in. shell guns, and 10-in. mortars, this number would be insufficient, the nature of the ordnance employed demanding a greater proportion of men than that for which the foregoing number was calculated. The detail for three reliefs in a siege train of 100 pieces exclusive of small mortars, might be estimated as follows :—

75 guns at 7 men each .....	525
25 large mortars at 7 men each .....	175
40 small do. at 5 men each .....	200
	<hr/>
Total, 140 pieces of ordnance requiring	900
	3
	<hr/>
Total for 3 reliefs .....	2700
For laboratory duties .....	100
Conductors of stores .....	25
Reserve to replace casualties, &c. ....	150
	<hr/>
Total .....	2975
	<hr/>

Should it be considered that three-fourths of the ordnance only would be in use at the same time, one-fourth might be deducted from the above. It is now proposed to give a detachment of ten men to each piece of ordnance to allow for all extra duties and casualties; this would come in the total to very nearly the same as above, reckoning for three reliefs.

The siege of Sebastopol was commenced with the two first battering trains sent out, and to these were attached eight companies of artillery, four to each train. As the number of ordnance mounted in the batteries increased, more companies were sent from England to join the siege train, until at the end of the siege the number of companies was about thirty; there being at that time 158 pieces of ordnance in the batteries manned by the Royal Artillery. Notwithstanding this large proportion of artillerymen, there were never sufficient to allow more than two reliefs during a bombardment, owing to sickness and other casualties.

Depôts and  
parks.

22. At the commencement of the investment of a fortress by a besieging army, it is necessary to establish artillery depôts and parks for the reception of the matériel required for the siege train; the former of these being generally on or near the coast, and the latter as close to the ground on which the batteries are to be placed as is compatible with safety from the enemy's fire, and also as circumstances will permit.

The matériel of the depôt is ordinarily in the charge of the Chief Commissary of Ordnance, under the general surveillance

of an officer of artillery of some standing ; the parks are under the care of subordinate ordnance commissariat officers.<sup>1</sup> The parks are kept supplied with ordnance, ammunition, &c. from the dépôts, and as it is from the latter that the batteries receive their armament and other stores, it is essential that during a siege the dépôts should keep the parks continually and amply provided with the same.

Great precautions are necessary both in the dépôts and parks, in order to avoid the chances of accident, and all persons employed in them or in their vicinity should be cautioned accordingly, as not only might much damage and loss of life be occasioned by an explosion, but there would also be a great probability of the progress of a siege being arrested by such an occurrence. There can be but little question, that the terrific explosion at the Windmill Park before Sebastopol, which took place on the 15th November, 1855, causing heavy casualties, especially to the French siege train, was occasioned by negligence or carelessness on the part of one of their sentries. The men of the siege train always encamp near the parks for which they usually furnish fatigues and guards.

Construction  
of batteries,  
magazines, &c.

23. The construction of siege batteries in our service does not form part of the duty of the artillery, as is the case with the French and other foreign powers ; their position and that of the guns should, however, be jointly determined by the Commanding Officers of the artillery and engineers, or else by a Committee composed of officers of these corps. The magazines in the batteries should not hold less than 100 rounds per gun, and there should be a separate magazine for every three or four pieces of ordnance ; Sir Charles Pasley's magazine holds 240 rounds per gun for three 24-prs. Besides the magazines, shell rooms are required for filling shells, boring and fixing fuzes, &c. When the firing is not very rapid, the latter should be performed under the inspection of an officer, and may be done with tolerable safety, if the non-commissioned officer or gunner on whom this duty devolves stand close under the merlon, and clear of the embrasure. The magazines should be in the charge of steady non-commissioned officers or men, permanently detailed for this service.

Arming of  
siege batteries.

24. The arming of siege batteries is carried on during the night, the guns being generally conveyed from the park across the open ground, though when the bottom of the trenches is sufficiently wide and firm, they may be taken along the latter. Horses should be made use of as much as possible in this transport, as such work tells heavily upon the men when added to their regular duties ; however, in arming the batteries of the

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<sup>1</sup> Officers of the Military Store Department.

third parallel, and those beyond it, this is often hardly feasible, and the pieces of ordnance, whether mounted on their own carriages or otherwise must then be dragged by the men. The conveyance of guns into the trenches, and the mounting of them in the batteries, should be conducted as silently as practicable.

Guns may be mounted during the daytime by means of luff tackle, gun tackle, &c., and in this case the embrasure should be temporarily masked; but a gyn should never be erected except at night, as the appearance of such an object above the parapet would be sure to draw down the enemy's fire upon the battery which would very probably injure the gyn, besides creating casualties. The number of ordnance in each battery will depend upon the purpose for which the battery is erected, the nature of the ground, &c.

Employment,  
&c. of the  
different  
natures of  
ordnance.

25. The employment in a siege of the different natures of ordnance and projectiles, as well as of the various kinds of fire, depends upon the end to be attained, and the relative position of the besieger's guns with reference to the works to be attacked. The solid shot guns, such as the 32-pr. and 24-pr. are specially intended for the destruction of revetments, and of other obstacles which offer much resistance; they also serve to dismount and otherwise damage the guns of the besieged fortress. Howitzer and shell guns are employed for the purpose of ruining the parapets, destroying the embrasures, traverses, &c., and for causing casualties among the defenders; they are never used for breaching, as hollow shot or shell have been found by experiment to be of but little use against masonry.

Both shot and shell guns are used for direct, enfilade, and ricochet fire,<sup>1</sup> the two latter being rendered necessary on account of the small surface which the guns or their carriages present to direct fire, either above the parapets or through the embrasures. Guns placed in the prolongation of the faces of a work for enfilade and ricochet fire, can often be disposed so as to admit of their being used for direct fire against the adjacent face, and then each of the foregoing descriptions of horizontal fire may be employed from the same battery, according as may be found desirable.

Vertical fire from mortars is chiefly used when it is required to reach those portions of the besieged town or fortress which are sheltered from direct, enfilade, or ricochet fire, such as magazines, barracks, and troops in large masses.<sup>2</sup>

Opening fire  
from the  
besieger's  
batteries.

26. In commencing a siege, the guns should not open fire until the batteries are sufficiently armed to be able to produce

<sup>1</sup> The different kinds of fire are described in Lecture IX.  
<sup>2</sup> The uses and employment of mortars, as well as of gun and mortar shells or other projectiles in a siege are more particularly described in Lecture III. Arts. 23, 24, and in Lecture VI. Arts. 19, 20.





are usually told off to form spiking parties. These should hold themselves in readiness to enter the enemy's works immediately on their being carried by the infantry, either in order to spike his guns, or turn them on any of his retreating columns. If the latter be intended, it will be necessary to carry cartridges in metal-lined cases or cartouches, with either common tubes and portfires, or friction tubes ; as for shot, it will be found in the enemy's batteries.

Fire preparatory to the assault.

31. Previous to an assault, it is generally the practice to endeavour as much as possible to silence the guns of the besieged place by a heavy bombardment or cannonade of some hours, from all the besieger's ordnance, which should especially be directed on those of the enemy's batteries, that would seem most likely to be able to annoy or cause much damage to the assaulting troops.

Captured ordnance, &c.

32. On the fall of a fortress, the captured ordnance and artillery matériel (an inventory of which should be taken) are generally handed over to the charge of the officer commanding the artillery of the victorious army, and under him to the charge of the chief commissary of ordnance and his subordinates ; should it not be the intention to dismantle the place, measures must be taken for putting it in as perfect a state of defence as possible, by repairing the batteries, magazines, platforms, &c. and by mounting ordnance wherever it may be considered desirable.

#### *Garrison Artillery.*

33. The service of artillery in the defence of fortresses and garrisons is of as great importance as in field service or sieges, the employment of this arm being essential in enabling the besieged to hold out against or resist with any prospect of success the attacks of an enemy provided with siege ordnance. Artillery is employed in the defence of fortresses, for the purpose of retarding and injuring the besieger's works, of counteracting and silencing the fire of his batteries, of creating casualties among his troops, and of repulsing such assaults as may be made by him.

Armament of fortresses.

34. The armament of fortresses and garrisons is governed in a great measure by the size and description of the works, as well as upon the nature of the locality on which they are situated, and is not based upon those principles which regulate the armament of a battering train, the question of transport, which influences in so great a degree the latter, being, as regards the arming of fortresses, of but little importance.

Description of ordnance for garrisons, &c.

35. For the defence of fortresses, the best nature of solid shot guns may be considered to be the two natures of 68-prs.,

and 32-prs. of 58, 56, and 50 cwt. respectively, and the 24-pr. of 50 cwt., the heaviest guns being placed in those positions which command the greatest extent of range.<sup>1</sup> The 10-inch shell gun and all the natures of 8-inch guns may also be employed with advantage, the 8-inch gun of 6-ft., as well as the 10 and 8-inch howitzers, and the 32-pr. of 25 cwt. being used for flanks, and short ranges. Of the mortars, the 13 and 10-inch would chiefly be made use of, though the 8-inch as well as the small brass mortars are also of service, the fire of the latter being very annoying to the working parties of a besieger. In addition to the foregoing, a certain proportion of field pieces are required for the defence of the covert ways, for sorties, &c.

Number of  
pieces of ord-  
nance.

36. There do not seem to be any fixed principles in our service on which to base the number of ordnance, or quantity of ammunition for the armament of a fortress; the French divide their fortresses into three classes, and apportion the number of pieces accordingly; the quantity requisite for the immediate security of a place is laid down at 10 pieces per bastion, this number providing for the armament of the salients and flank defences, and also allowing for the heavy mortars; but that required to sustain a siege must depend on the extent of the works generally, thus fortresses of the

1st class consisting of 10 sides and upwards,	require 110 pieces,
2nd do 6 to 10 sides	do 70 „
3rd do 4 to 6 sides	do 30 „

in addition to the 10 per bastion.

Piobert gives from 300 to 400 pieces for the larger fortresses, and sets down the armament of such a place as Paris, at upwards of 2000 ordnance.

It will therefore be seen that the extent of the works to be defended must be the ruling principle as regards the arming of a fortress or garrison.<sup>2</sup> A larger proportion of shell guns may in general be used in the armament of fortresses than in that of siege equipments, there being no masonry to breach or overthrow, and shells being of more service against earthworks and troops than solid shot. Shells can, however, be fired from 32 and 68-pr. guns, as well as from the shell guns and howitzers.

The French *Aide Memoire* of 1856, gives the following as the proper per centage of guns, howitzers or canon-obusiers, and mortars, for the defence of a fortress; this includes both the small mortars and field-pieces :—

<sup>1</sup> The 56-pr. guns are not included either in the defence of fortresses or coasts, although many are still used for these purposes, for owing to their supposed deficiency in strength they are now no longer manufactured, as before stated, and they have therefore been omitted in this Lecture.

<sup>2</sup> A certain proportion of spare pieces of ordnance are also required to replace those which may become unserviceable.

Gun . . . . .	54
Howitzers, &c. . .	26
Mortars . . . . .	20
	<hr/>
	100
	<hr/>

In our service, it is generally considered desirable to employ a larger per centage of shell guns or howitzers than the foregoing, chiefly for the reasons before stated.

Quantity of  
ammunition.

37. The quantity of ammunition required for the defence of a fortress is regulated by its extent, the nature and number of pieces of ordnance mounted in the works, and also in some measure, by the probable duration of any siege it may have to sustain. In the defence of a great arsenal such as Sebastopol, there would be scarcely any limit to the quantity of shot and shell available for use, and though it has been considered that in ordinary fortresses, no more ammunition should be stored than that necessary for a vigorous defence, yet this could not be the case with regard to an arsenal, where there must always be an immense quantity of war matériel ready for service. The proportion of ammunition per piece, depending as regards its extreme limits on the number of rounds each will bear before becoming unserviceable, has been laid down by the French, according to the class of fortress to be defended, and the position of the pieces, that is to say, as to whether they are mounted on such faces of the fortress as are susceptible of a regular attack or not.

The following Table of Ammunition is taken from the *Aide Memoire à l'usage des Officiers d'Artillerie*, Ed. 1856.

Class of Fortresses.	No. of rounds (not including case).					Case Shot.		
	Per gun. <sup>1</sup>	Per howitzer, and canon-obusier of 80.	Per mortar.			Per gun.		Per howitzer, and canon-obusier of 80.
			32c and 27c	22c.	15c.	30	19	
						24	and 8	
						16		
For the fronts exposed to regular attack.								
1st	1000	800	800	1200	800	25	60	30
2nd	800	600	600	900	800	29	40	25
3rd	600	500	400	800	600	20	40	25
For the fronts not exposed to regular attack. <sup>2</sup>								
1st	300	250	180	250	...	12	30	15
2nd	250	200	130	200	...	10	20	12
3rd	200	150	90	150	...	10	20	12

The above though a fair proportion of ammunition might be increased, at all events in the case of the solid shot guns and

<sup>1</sup> One-third of these to be shells or hollow shot for the 30 and 24-pr. guns.  
<sup>2</sup> Places or forts not susceptible of a regular attack, will require the same proportion of ammunition as that given for the front of a fortress under similar conditions, according to their class.

heavy mortars, and in addition to the projectiles mentioned in the foregoing Table a certain quantity of shrapnel shells for the guns, and of light balls and pound shot for the mortars should be provided, these latter being very efficacious against the defenders of the besieger's advanced trenches when he has arrived at the distance of from 200 to 300 yards from the place. From these tables and proportions it may therefore be deduced that a fortress of very large size would require from 200,000 to 300,000 projectiles, the smaller ones from 40,000 to 50,000, and forts from 15,000 to 20,000. The quantity of powder is calculated in the same manner as for siege equipments (see Article 14 of this Lecture).

Carriages,  
platforms, &c.

38. The guns of a fortress are generally mounted on wooden standing garrison carriages, though all the natures of naval as well as siege carriages may be employed if desirable, or if there be not a sufficient number of the first-named description. Spare carriages in the proportion of from  $\frac{1}{3}$  to  $\frac{1}{4}$  the number of guns should also be furnished, as a great number are almost sure to be rendered unserviceable during a siege. Mortars are provided with the same beds as in siege trains. The platforms to be preferred are the ground platforms, constructed either of wood or stone, and the dwarf traversing platforms, the latter being chiefly used for mounting guns in the salients of works. In casemated fortresses, a low traversing platform may also be made use of. The carriage used on these platforms, as before stated, is merely the ordinary garrison carriage, with the substitution of blocks of wood for the iron trucks, and the addition of a small truck in front of each bracket.<sup>1</sup> For the transport of ordnance in a garrison, the sling cart and sling wagon are peculiarly adapted, and for the 10 and 8-inch mortars, trench carts are also very useful; indeed, most of the carriages used for siege purposes are applicable for the transport of guns in fortresses and coast batteries.

Gyns and  
sheers.

39. Among the artillery matériel which must be provided in calculating for the defence of a fortress, a certain number of triangle gyns (complete), as well as the spars, tackle, &c. for sheers are very necessary, though no definite proportion of each can be laid down. Sheers are especially useful when it is requisite to mount guns on towers, or to perform any work for which the gyn might not be considered adequate; the cheeks of the gyn may however in many cases be made to supply the place of sheers. In casemates or galleries, such as those at Gibraltar, the Gibraltar gyn is applicable, for although a more tedious method of mounting guns than by making use of skidding and

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<sup>1</sup> For description of carriages, &c. see Lecture V.

luff tackle, it can be more easily managed by men not perfectly drilled in the service and shiftings of heavy ordnance.

Proportion of  
men.

40. The proportion of gunners allowed per piece of ordnance in the defence of a fortress or garrison, will generally be less than that calculated for the attack. In France three men per gun, estimating for three reliefs, has been the number laid down, the rest of the detachment being made up of soldiers of the line. In our service, however, where the line regiments are but seldom drilled with heavy ordnance, their numbers also being generally insufficient, a larger proportion of artillerymen would be required in order that the guns might be worked efficiently.

Employment  
of artillery in  
the defence of  
a fortress.

41. In the defence of a fortress, the guns should be placed so as to defend all the approaches to it, the positions of the different descriptions of ordnance being determined by their respective powers and natures. Previous to the investment by an enemy, and indeed, at all times, the artillery officers should make themselves acquainted with the exact distance from their guns of every object in the surrounding country, such as trees, hillocks, buildings, &c. which may happen to be within range, as this will enable the fire of the besieged to be executed with precision at the time when the besiegers are laying out their batteries, and to maintain a superiority in this respect over that of the enemy after his batteries are armed; at all events, until such time as he may have ascertained the different ranges by trial. On the investment of the fortress, the artillery of the besieged should endeavour to annoy and harass the enemy as much as possible and hinder his progress, and on the night on which it is supposed he is first breaking ground, a heavy fire of shot, shell, and shrapnel, should be kept up across the ground where his working parties are engaged; light balls being also employed to ascertain the position of the latter.

During the second period of the attack, i.e. until the besiegers batteries are fully armed, the artillery of the place is paramount and usually undisturbed by the fire of guns or mortars; this advantage should not therefore be thrown away, but every effort should be made to dismount the enemy's guns, destroy his magazines, &c. and thus delay the progress of the siege. When the fire of the besieger is in full force, the ordnance in the salients and covert ways should be withdrawn and placed in the most advantageous interior positions, the dismounted pieces removed, and the ammunition economized for the last effort viz. the attempt to destroy the breaching batteries, and impede the final advance of the besiegers, by a new disposition of the flank defences. In opposing the enemy's assaults, grape and case shot may be employed with the greatest advantage, and

previous to this period, guns should be so disposed as to obtain a very heavy cross fire on those parts of the glacis, &c. over which the besiegers attacking columns may have to pass. Finally, should it be desirable, and at the same time feasible to evacuate the fortress, all the ordnance and artillery matériel left in the place should be rendered unserviceable and damaged in such a manner, that the enemy on taking possession may be able to make no further use of, or derive any benefit from their acquisition.

#### *Coast Batteries.*

42. Artillery is used in coast batteries and defences to protect the entrances of harbours and ports, to defend the different dockyards, to oppose the landing of an enemy on any part of the coast, and to prevent the approach of his vessels, either for any aggressive purposes, or for taking soundings, observations, &c.

Armament of  
coast defences.

43. The armament of coast batteries depends chiefly on the nature of the coast which they are required to defend, and the facilities afforded by it for the landing of an enemy; the depth of water in shore; and the object of such battery or batteries, whether this object be to command the approach to a harbour or landing place, to cover a roadstead, &c.

Nature of  
ordnance for  
coast defences.

44. In the Report of the Committee on Coast Batteries, dated July, 1860, and approved by H. R. H. the Duke of Cambridge, five different natures of smooth-bored ordnance are recommended for the armament of coast batteries; these are,

The 10-in. gun of 86 cwt.

68-pr. „ 95 „

8-in. „ 65 „

32-pr. „ 56 „

18-in. sea service mortar.

“The 68-pr., 8-in., and 32-pr. guns are considered the best for coast defence generally, as being of considerable power, and capable of setting fire to shipping, either by means of common or mortar shells, or of hot shot, and are those which at present enter most commonly into the armament of coast batteries.

“The 10-in. gun, though not to be depended upon for accuracy at long ranges, is retained as a useful gun for positions where ships are likely to engage at short ranges, on account of its large calibre, which renders the shell so formidable a missile if exploding between a ship's decks, or when filled with liquid iron.

“The proportion of shot and shell guns to be employed must always depend upon local circumstances; but, when practicable,

it is advisable to have all the guns in a battery of the same calibre."

The Committee consider that mortars should only be placed on the sea defences of our principal dockyards, and not in coast batteries generally; under certain circumstances, for instance, in firing upon a large fleet or squadron of vessels, their shells would no doubt prove very destructive. In addition to the guns recommended by the Committee, 18-pr. iron guns are now used for the batteries of position, and employed as a means of connecting the line of batteries or forts erected along the coast, and of defending those situations where permanent batteries do not exist; one of Sir W. Armstrong's rifled guns is however likely before long to supersede the 18-pr. for this service.

45. The Committee stated that with regard to rifled ordnance they had not been provided with official information, but "they consider that in no position will rifled guns of long range and great precision, combined with facility in working, be found of greater advantage than in coast batteries." Waterproof coverings are recommended to protect rifled guns from spray and dampness. The 100-pr. and 40-pr. Armstrong rifled guns will most probably be employed for coast batteries.

Ammunition.

46. Coast batteries should be provided with sufficient ammunition for at least one day's firing, the general proportion of made up ammunition being laid down by the Committee at 200 rounds per gun. The relative proportions of the different natures of projectiles to be:—

For the 10-in. gun,

	Rounds.
Common shells . . . . .	150
Martin's do . . . . .	30
Case and grape . . . . .	20
Total . . . . .	200

Or if not provided with a cupola,

Common shells . . . . .	180
Case and grape . . . . .	20
Total . . . . .	200

For the 68-pr. gun,

Solid shot . . . . .	90
Common shells . . . . .	50
Shrapnel do . . . . .	15
Case and grape . . . . .	20
Martin's shells . . . . .	25
Total . . . . .	200

Or if not provided with a cupola,

	Rounds
Solid shot . . . . .	100
Common shells . . . . .	65
Shrapnel do . . . . .	15
Case and grape . . . . .	20
Total . . . . .	200

For the 8-in. gun,

Common shells . . . . .	140
Martin's do . . . . .	25
Shrapnel do . . . . .	15
Case and grape . . . . .	20
Total . . . . .	200

Or

Common shells . . . . .	165
Shrapnel do . . . . .	15
Case and grape . . . . .	20
Total . . . . .	200

For the 32-pr. gun,

Solid shot . . . . .	150
Common shells . . . . .	15
Shrapnel do . . . . .	15
Case and grape . . . . .	20
	200

"In case the 32-pr. should form the sole armament of a battery, the number of shells to be increased to 25, and of solid shot reduced to 140."

All coast batteries armed with solid shot guns should be provided with Addison's shot furnaces. The cupola furnace for heating the iron for Martin's shells would be generally supplied to all batteries, which are provided with 68-pr. and 10-in. or 8-in. guns.

The powder should generally be made up into cartridges, and kept in metal-lined cases, but a small proportion of loose powder (one barrel per gun) with the requisite number of flannel cartridges is also recommended. A certain proportion of rockets might be found useful for the protection of breaches, &c.

Carriages,  
platforms, &c.

47. The ordinary garrison carriage, and the carriage for traversing platforms and naval slides, are the best adapted for service in coast batteries, though all the natures of naval



carriages may be made available, as in the defence of garrisons and fortresses. Where rapidity of fire is not needed, the common ground platform of wood or stone may be used, but for quick firing at vessels in motion, the dwarf traversing platform is the most suitable; the naval slide may also be used on an emergency for the same purpose.

Employment  
of artillery in  
coast batteries.

48. The objects against which the guns of coast batteries are employed being generally movable, very great accuracy and rapidity of fire are essential, well trained gunners with good pieces, which can be readily laid and traversed, being therefore required; it will also be necessary in most cases to have guns of great power as regards range, for it is very desirable to prevent a vessel from closing with the battery, by disabling her when at a considerable distance. A vessel has usually a great superiority over a battery in the number of guns she can bring to bear upon a given point, but the advantages of the battery are, that the guns are fired from a steady platform, that the battery, unless it be on a level with the water, does not present so good an object as the vessel, and that the ranges would generally be known to the gunners in the battery; a battery cannot be set on fire like a ship, and the effect of shells upon the former, especially if it is an open earthwork, is comparatively trifling to the destruction caused by their bursting inside a vessel; moreover, a battery possesses the numerous advantages which choice of position can give. Iron plated vessels can no doubt be made secure from the effect of horizontal shell firing from smooth-bored pieces, but, unless the iron be of great thickness, elongated shells fired from rifled guns will most probably be able to penetrate the metal and enter a ship.

In order that guns may be employed with the greatest advantage in coast batteries the different depths of water within range should be ascertained, as in case of an attack it can be judged approximately, from the size and class of the attacking ships, to within what distance from the shore they are likely to be able to approach; buoys may also be anchored to indicate the several ranges.

Vessels of war draw about the following depths of water, viz.

	Feet.
1st rate . . . . .	36
2nd . . . . .	30
3rd . . . . .	24
4th . . . . .	18
Paddle steamers . . . . .	15 to 21

Common shells are generally considered to be far more destructive to shipping (see Art. 22, Lect. VI.) than solid shot, even though the latter be heated; moreover, they require but

little time and trouble to prepare them, which is not the case with hot shot or shells filled with molten iron. In the event of a coast battery being attacked by boats, shrapnel shells and case should be used, round shot being fired to sink the boats. Shrapnel fired on to the deck of a vessel would prove very destructive.

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ANCIENT MACHINES.

Plate 1.

Fig. 1.  
*Balista.*

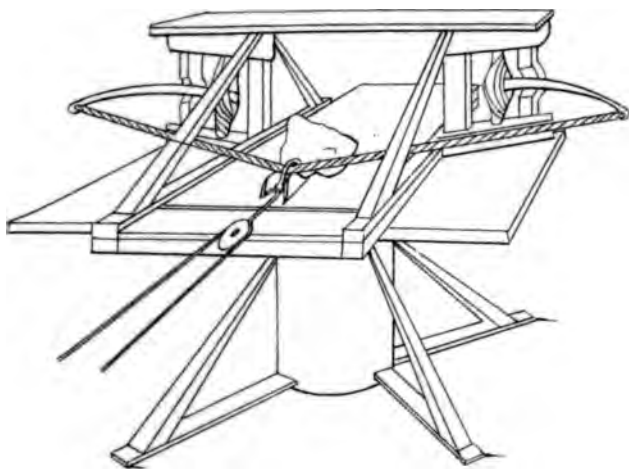


Fig. 2.  
*Catapulta.*

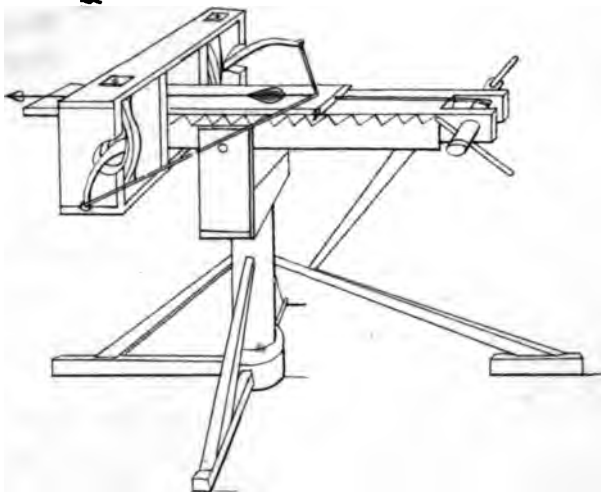


Fig. 3.  
*Battering Ram.*

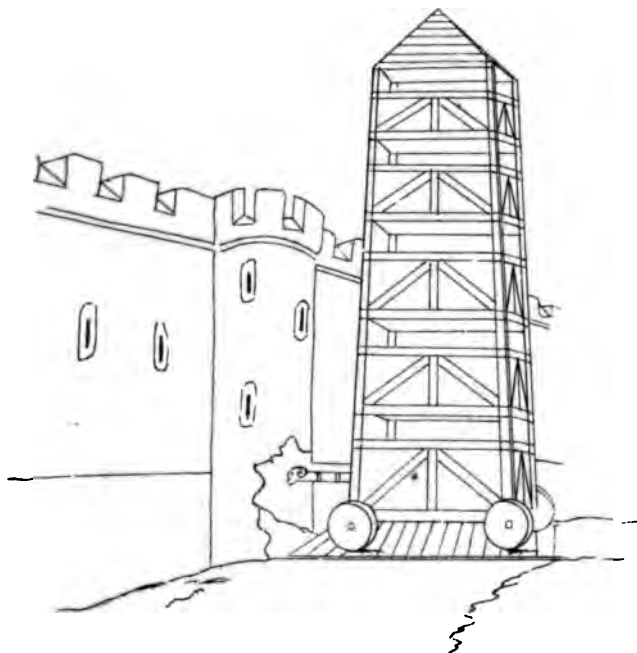
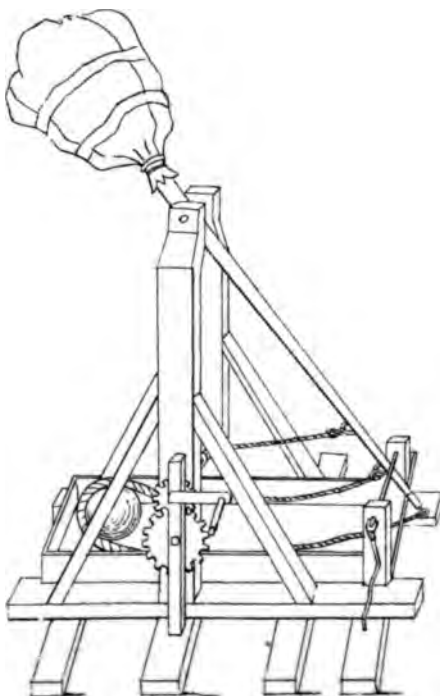


Fig. 4.  
*Trebuchet.*



*Lithographed at the Royal Artillery B*



Fig. 1.

*Ancient hooped Cannon in Wooden Bed.*

*14<sup>th</sup> Century.*

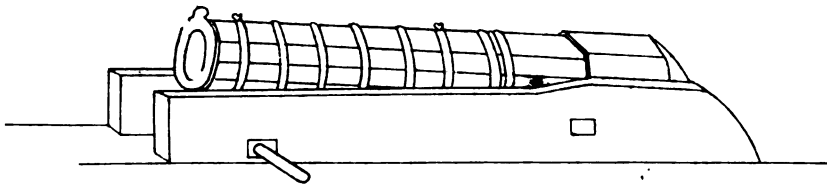


Fig. 2.

*Bombard and Carriage.*

*15<sup>th</sup> Century*

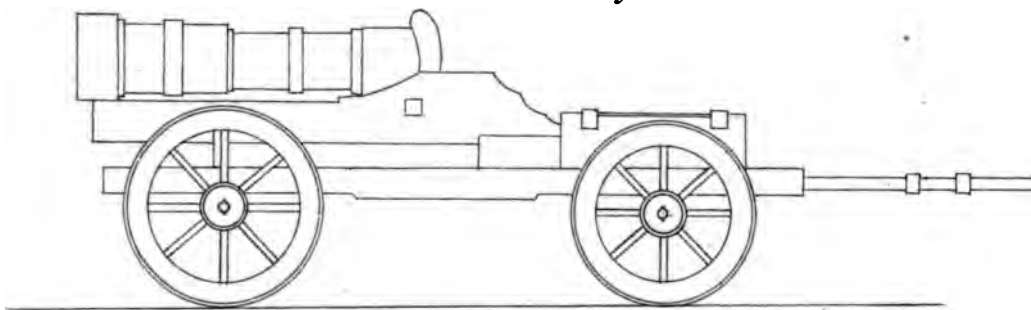


Fig. 3.

*Long Serpentine of Wrought Iron.*

*15<sup>th</sup> Century.*

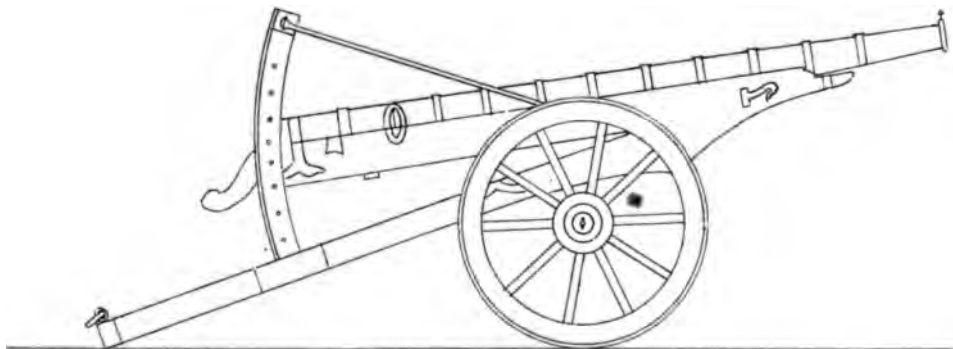
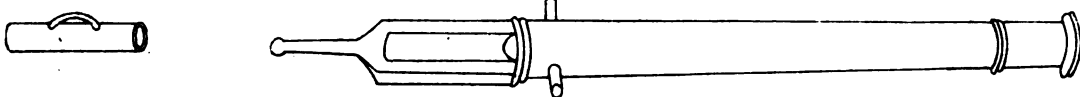


Fig. 4.

*Pierrier or Paterera.*

*16<sup>th</sup> Century.*





Modern Ordnance . (Smooth-bored.)

Fig. 1.- 32 P<sup>r</sup> Gun. (58 Cwt.)

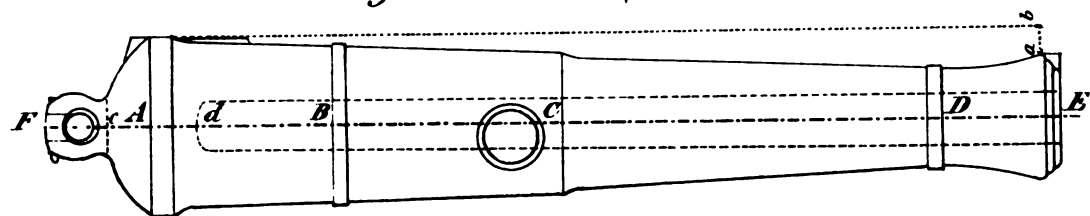


Fig. 2.- 8 Inch Shell Gun. (52 Cwt.)

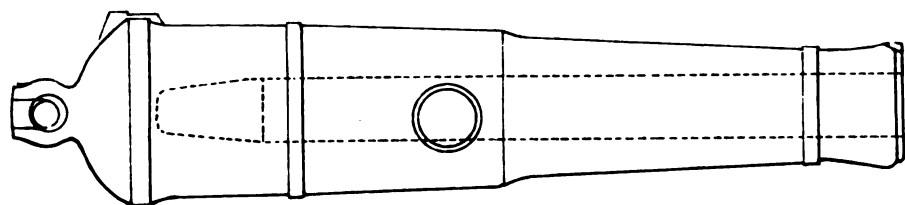


Fig. 3. 8 Inch Mortar (L.S.)

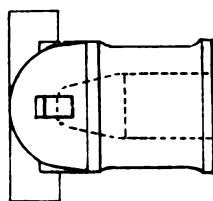


Fig. 4. 68 P<sup>r</sup> Carronade.

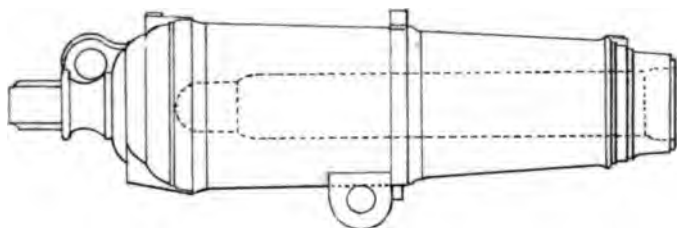
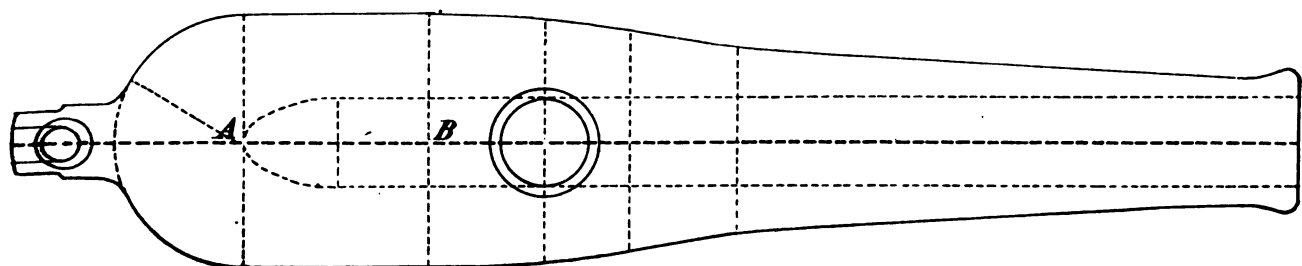


Fig. 5. Dahlgren's 11 Inch Shell Gun. (American.)



Scale.  $\frac{1}{2}$  in.

Lithographed at the Royal Artillery Institution.





Fig. 1.

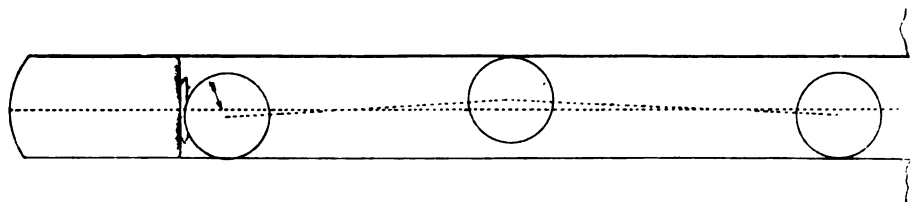


Fig. 2.  
Gomer.

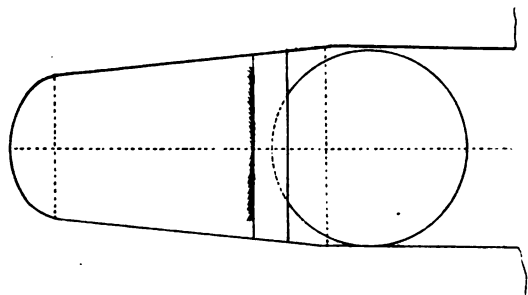


Fig. 3.  
Cylindrical.

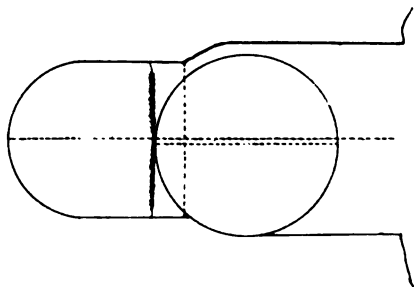


Fig. 4.  
French.

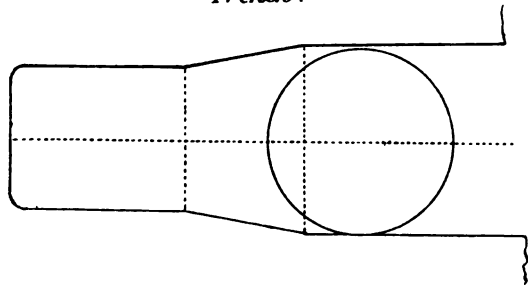


Fig. 5.

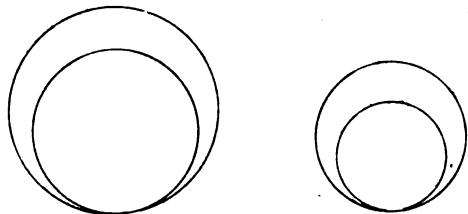


Fig. 6.

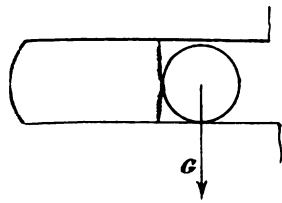


Fig. 7.

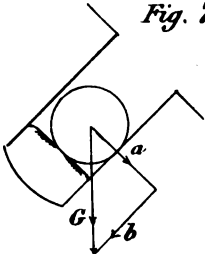


Fig. 8.

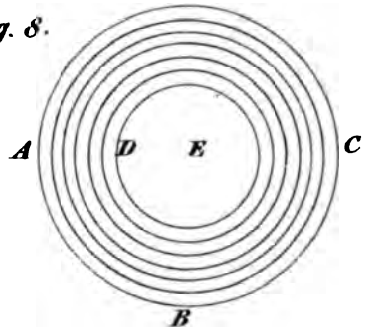


Fig. 9.

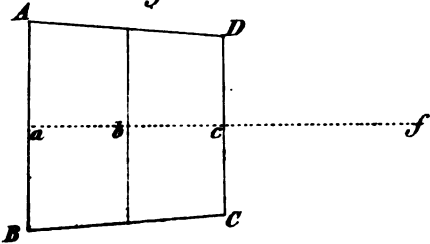
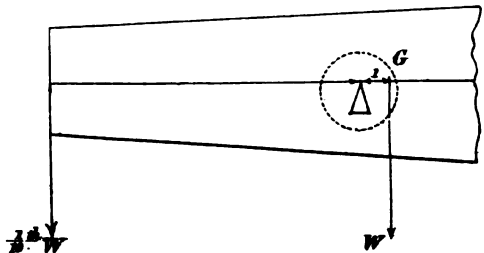
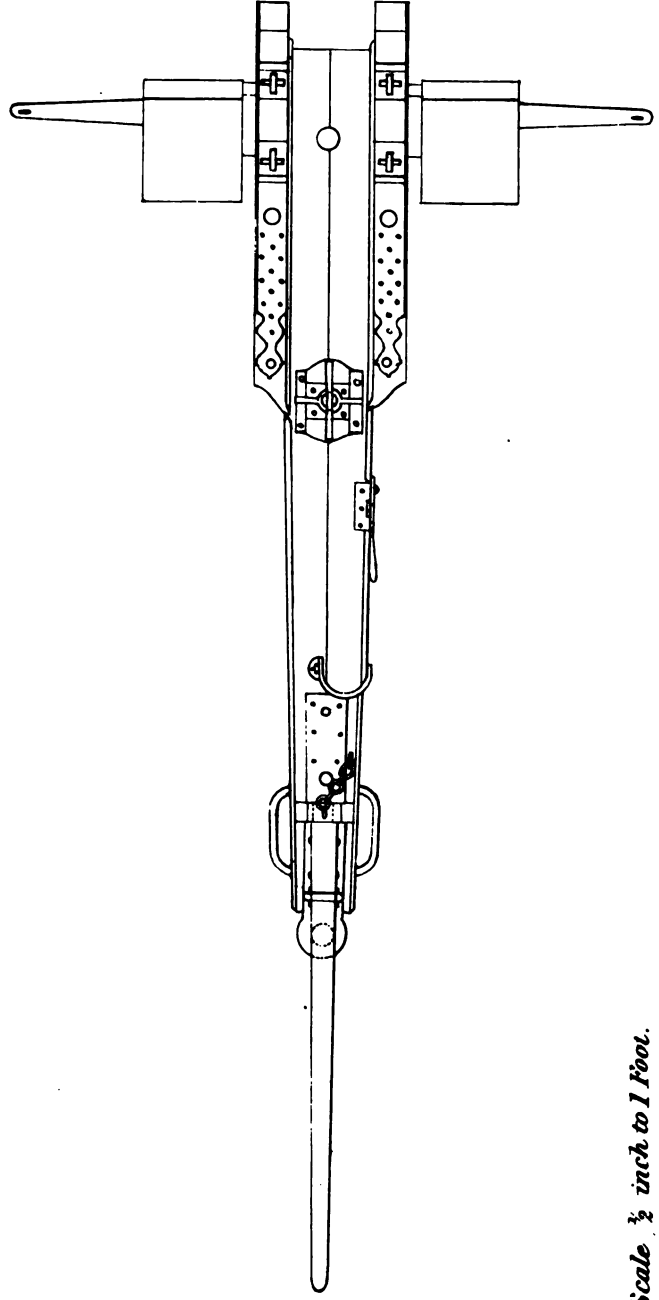
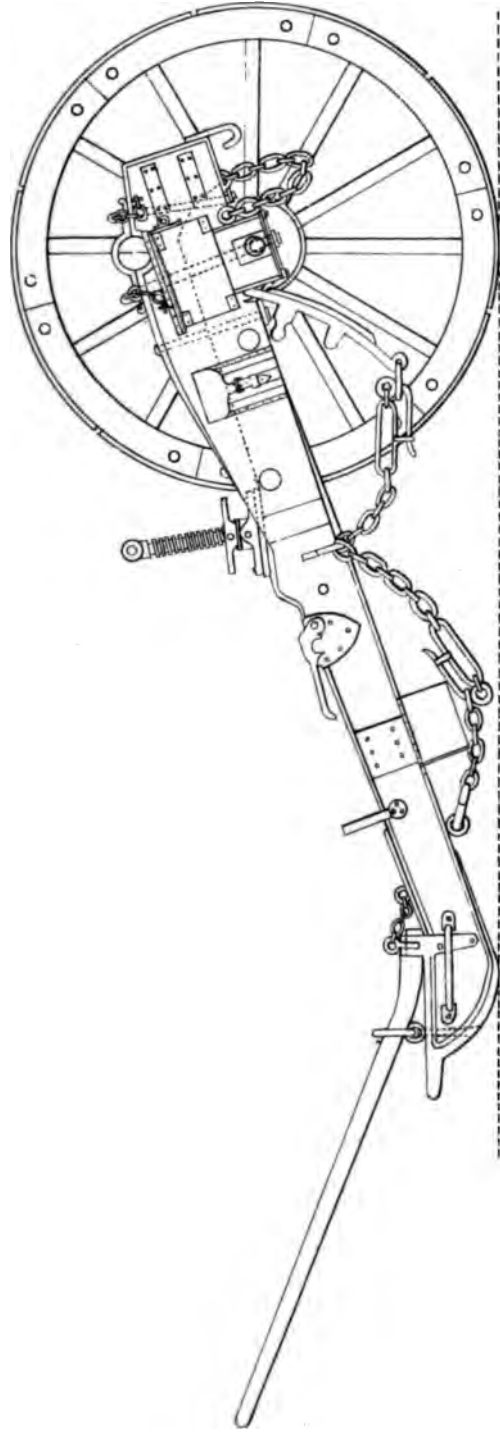


Fig. 10.





*9 P<sup>r</sup> Field Gun Carriage.*

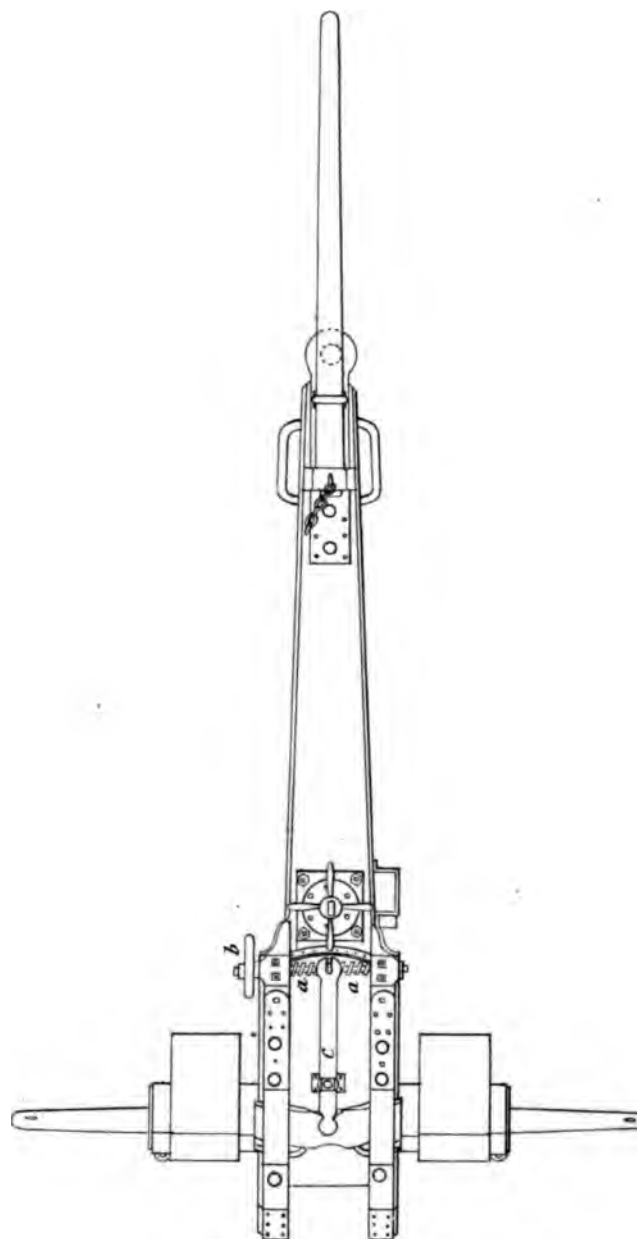
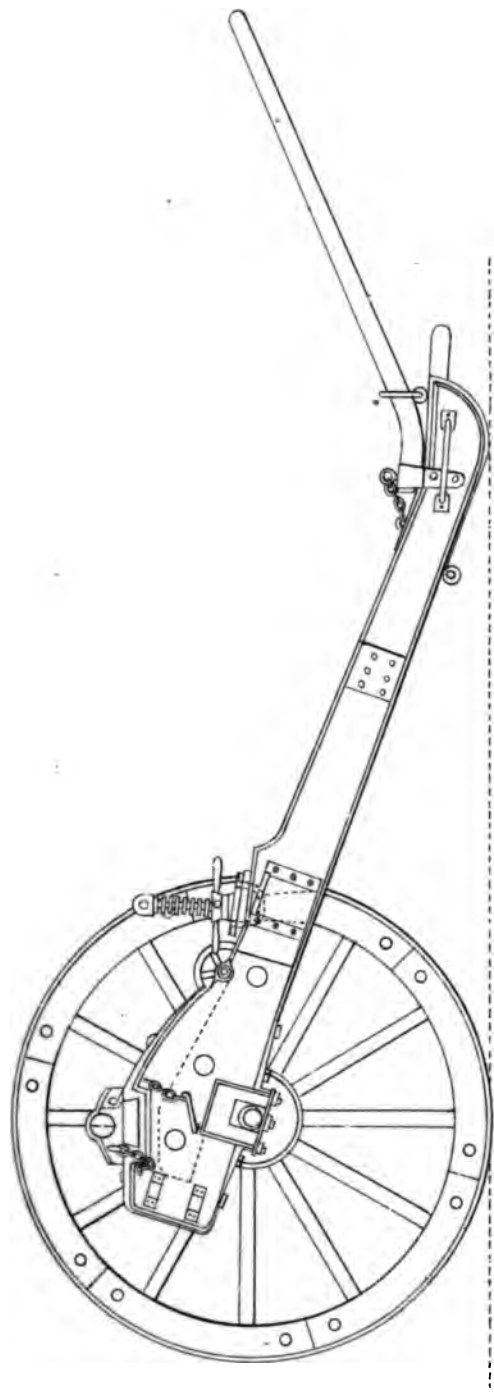


*Scale  $\frac{1}{2}$  inch to 1 Foot.*

*Drawn by Sgt. Hughes R.A.*

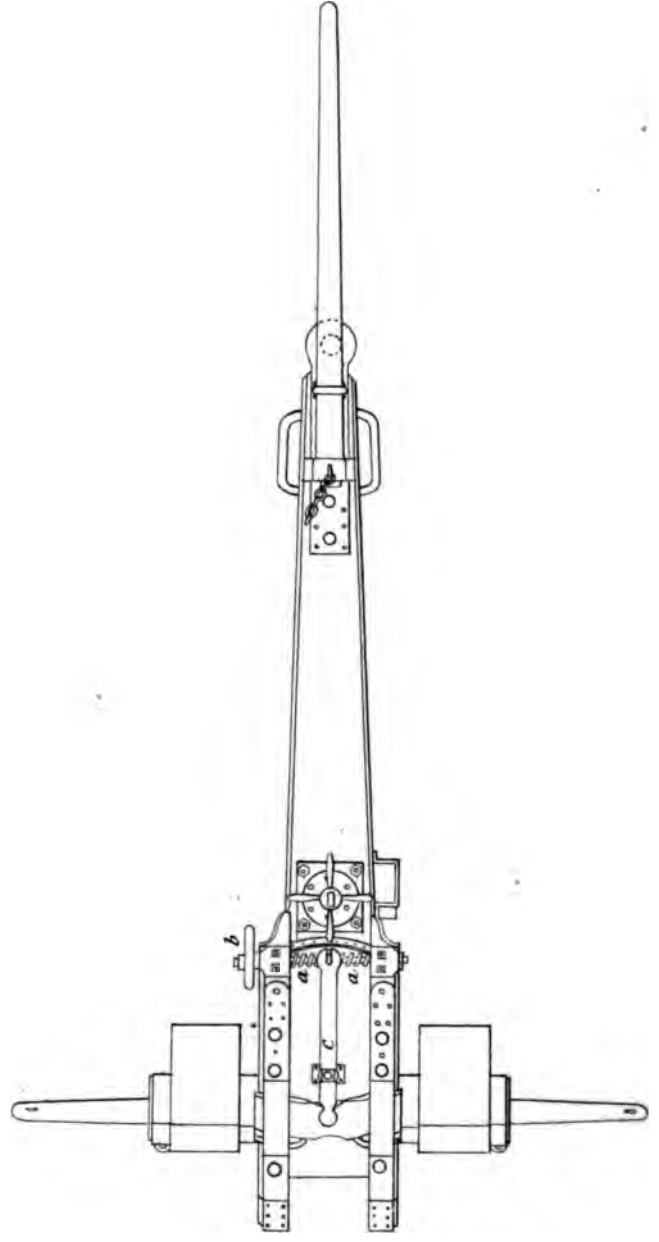
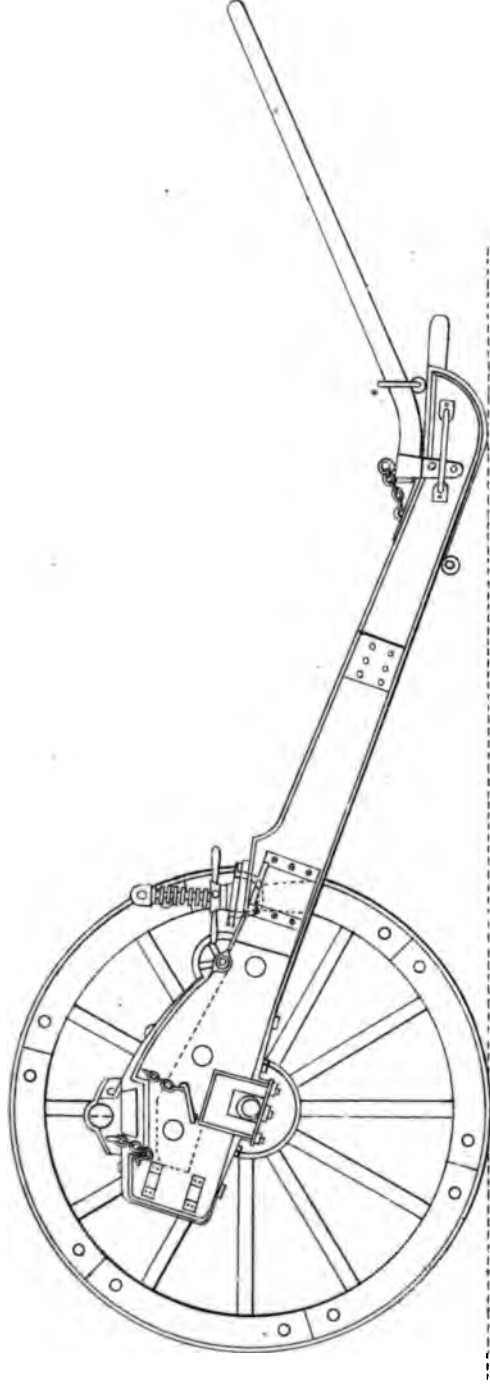


*Field Gun Carriage for Armstrong Gun (12 P.)*





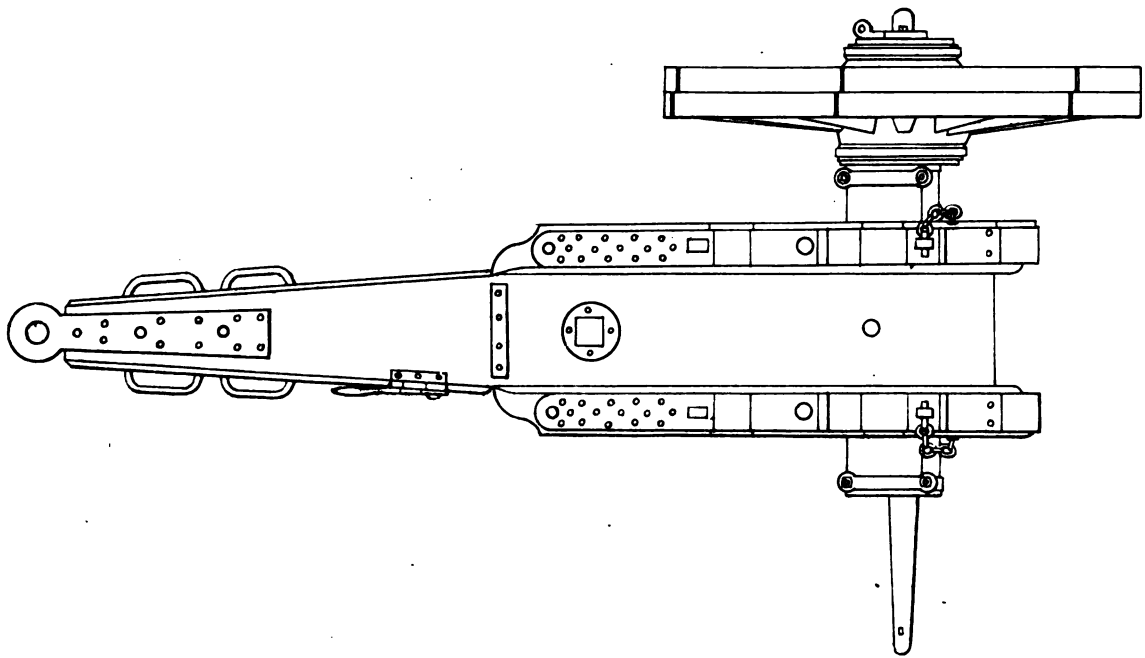
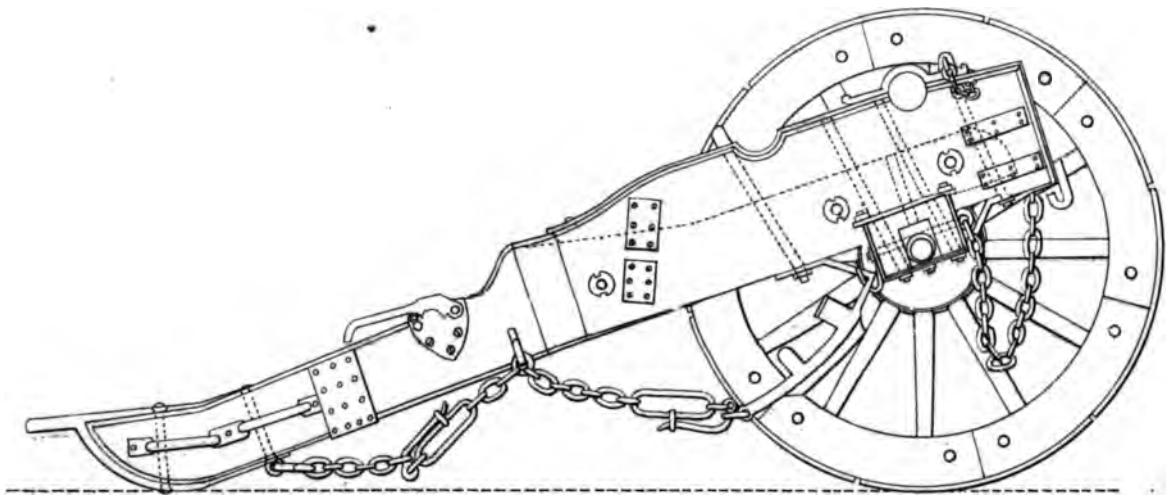
*Field Gun Carriage for Armstrong Gun (12 Pr.)*







18 P<sup>r</sup> Block Trail Carriage.



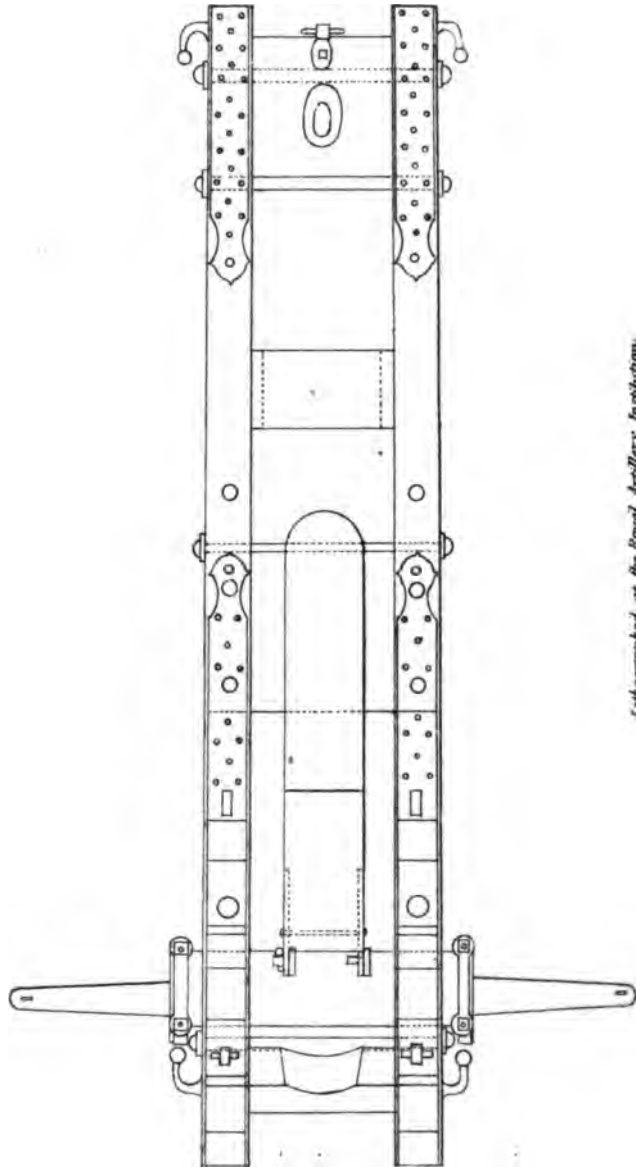
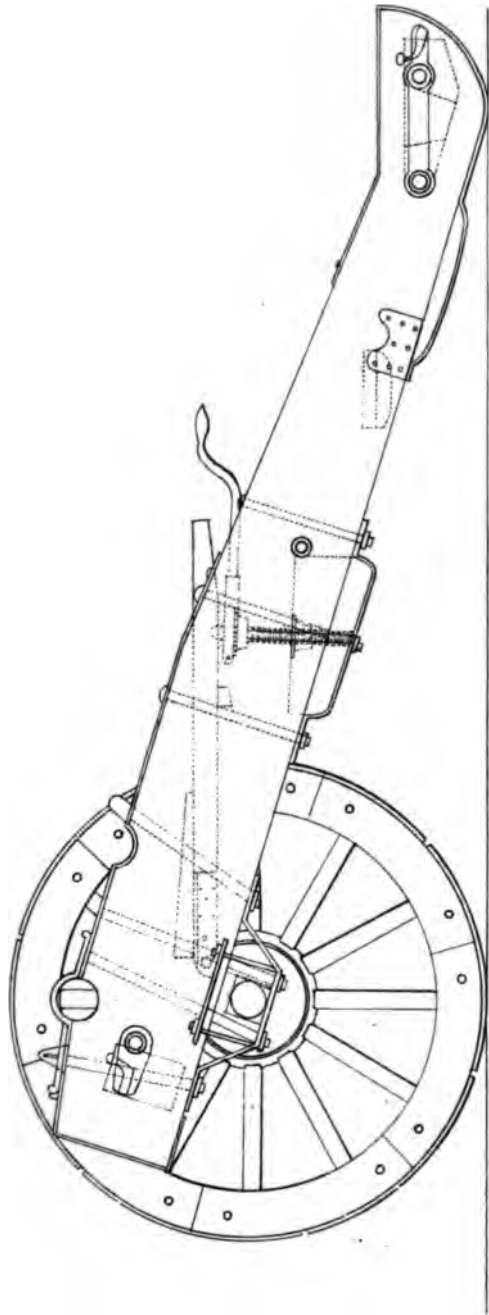
Scale.  $\frac{1}{2}$  Inch to 1 Foot.

Drawn by Serg<sup>t</sup> Inglis R.A.

Lithographed at the Royal Artillery Institution.



24 P<sup>r</sup> Siege Carriage.



Scale.  $\frac{1}{2}$  Inch to 1 Foot.

Lithographed at the Royal Artillery Institution.

Drawn by Serg<sup>t</sup> Hughes R. A.



Fig 1.  
*Ammunition Waggon.*

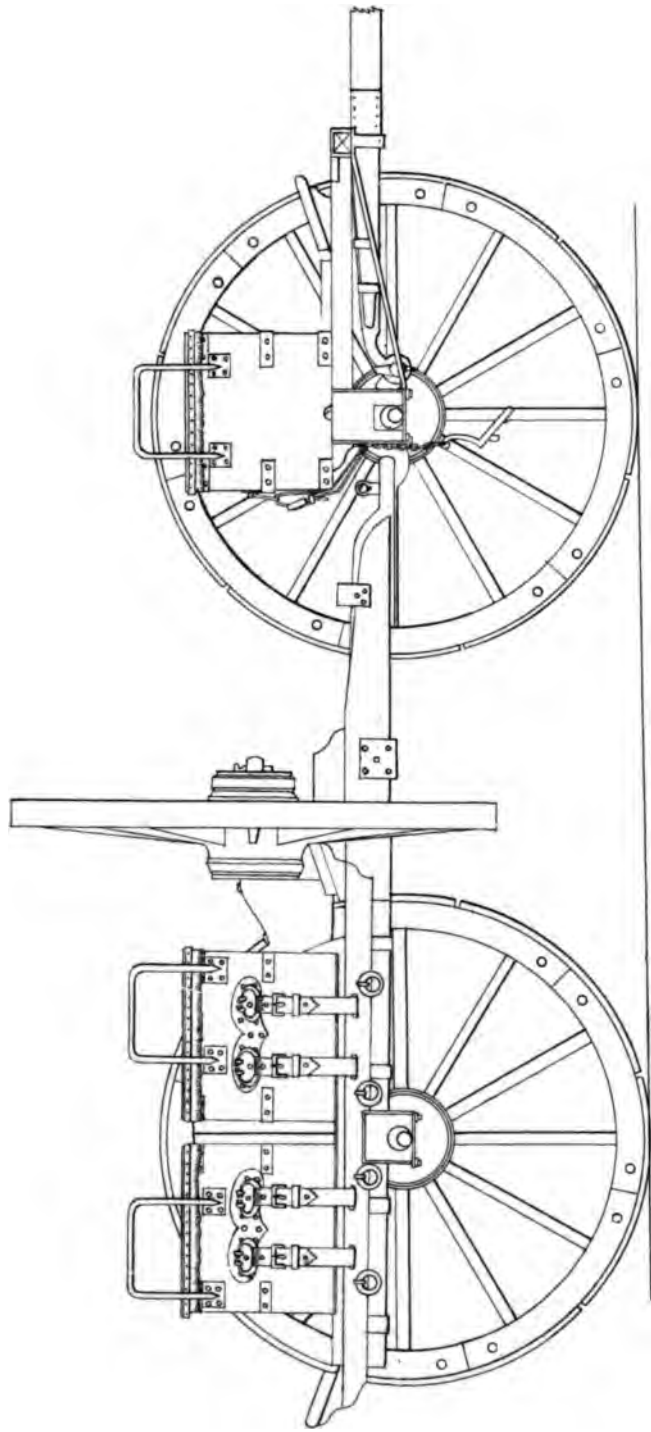
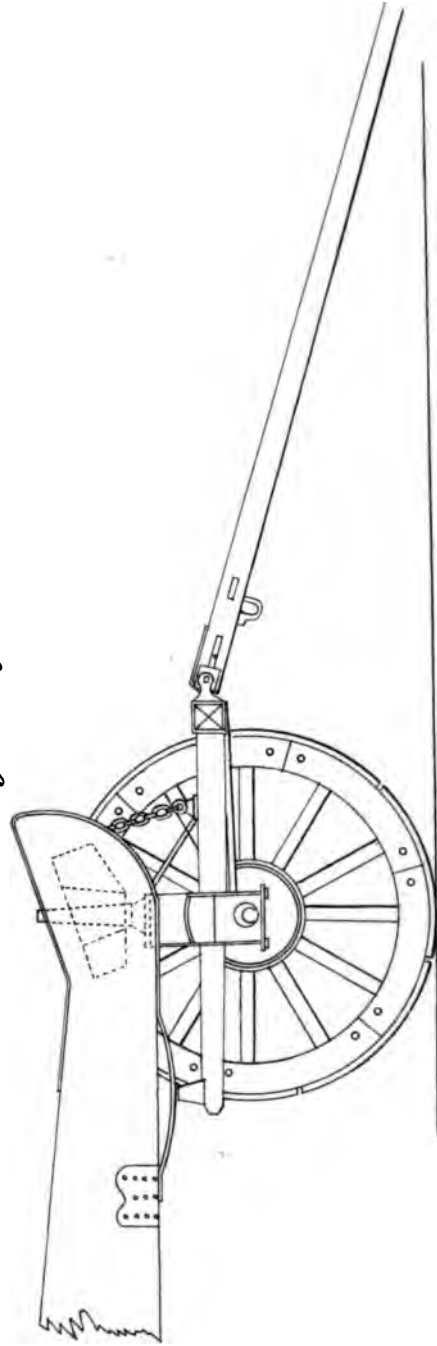


Fig. 2.  
*Limber for Siege Carriage.*



Scale:--  $\frac{1}{2}$  Inch to 1 Foot.

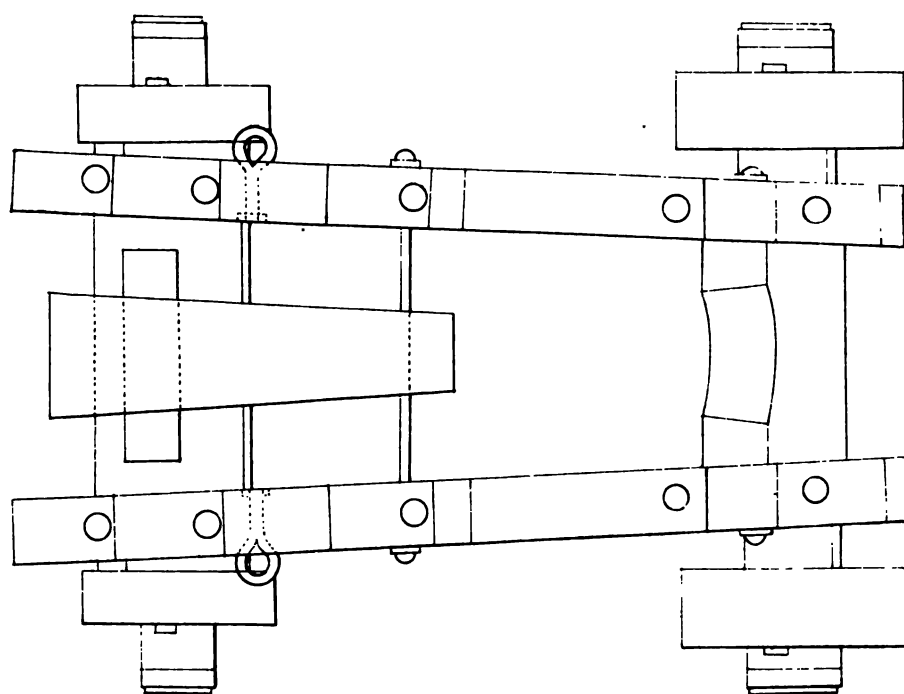
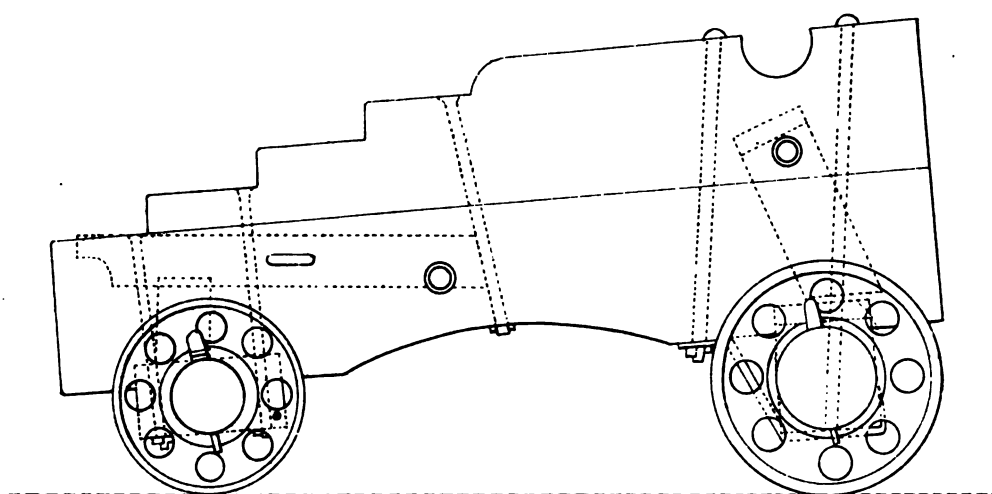
Drawn by Serjt. Englis R. A.

1855. 1856. 1857. 1858. 1859. 1860. 1861. 1862. 1863. 1864. 1865. 1866. 1867. 1868. 1869. 1870. 1871. 1872. 1873. 1874. 1875. 1876. 1877. 1878. 1879. 1880. 1881. 1882. 1883. 1884. 1885. 1886. 1887. 1888. 1889. 1890. 1891. 1892. 1893. 1894. 1895. 1896. 1897. 1898. 1899. 1900.



*Garrison Standing Carriage.*

*(for 24 P<sup>r</sup> Gun.)*



*Scale.  $\frac{3}{4}$  Inch to 1 Foot*

*Drawn by Serg<sup>t</sup> Ingle & d*

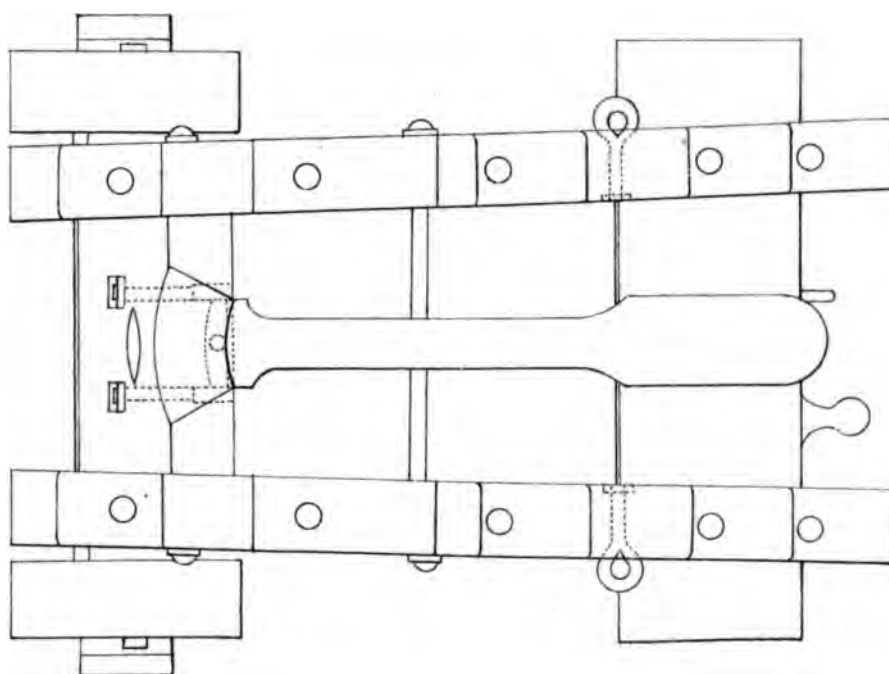
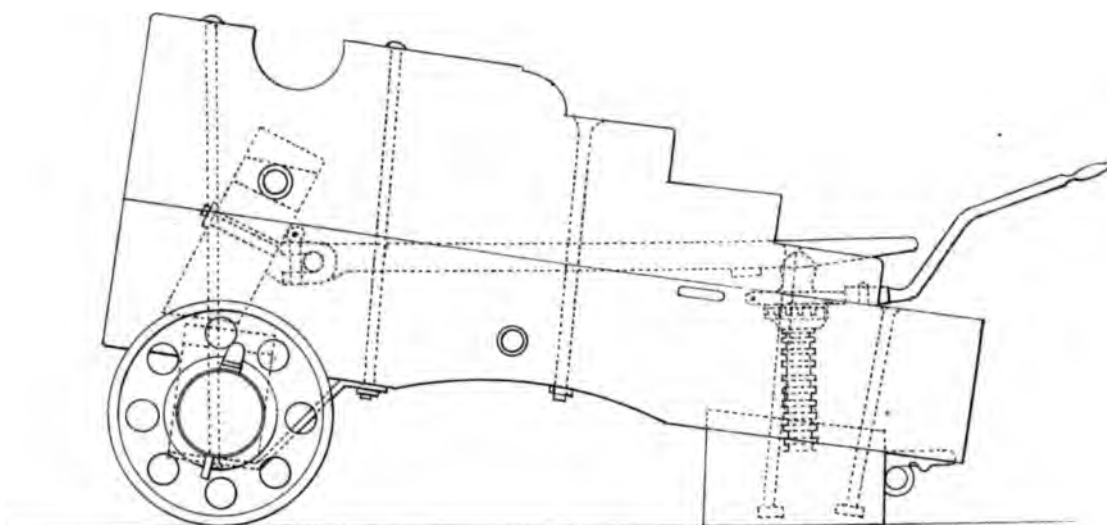
*Lithographed at the Royal Artillery Institution.*





*Rear Chock Carriage.*

*( for 8 Inch Gun )*



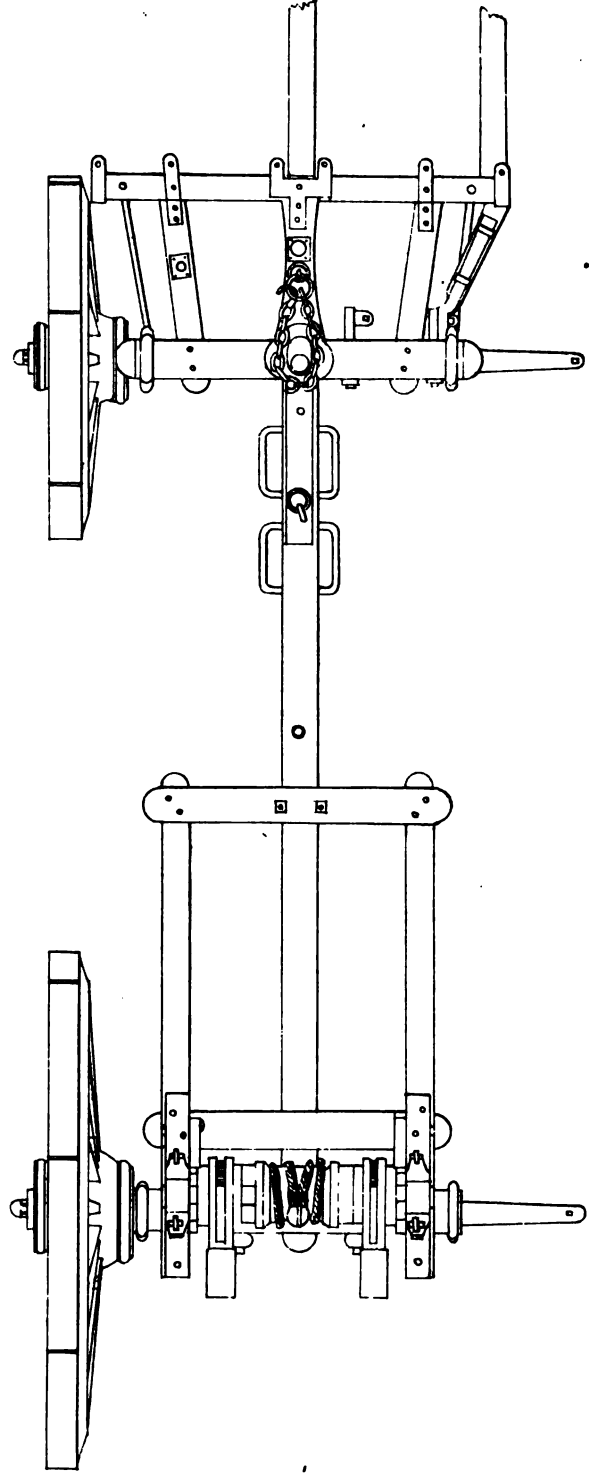
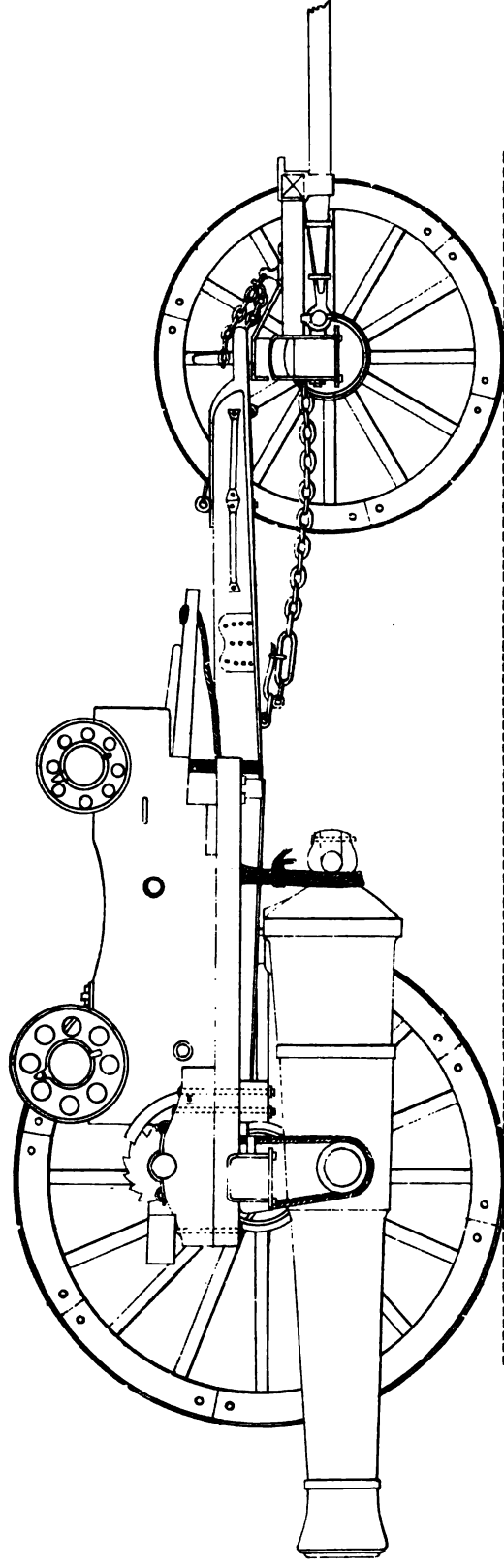
*Scale.  $\frac{3}{4}$  Inch to 1 Foot.*

*Drawn by Serj<sup>r</sup> Inglis & A*

*Lithographed at the Royal Artillery Institution.*



*Sling Waggon.*



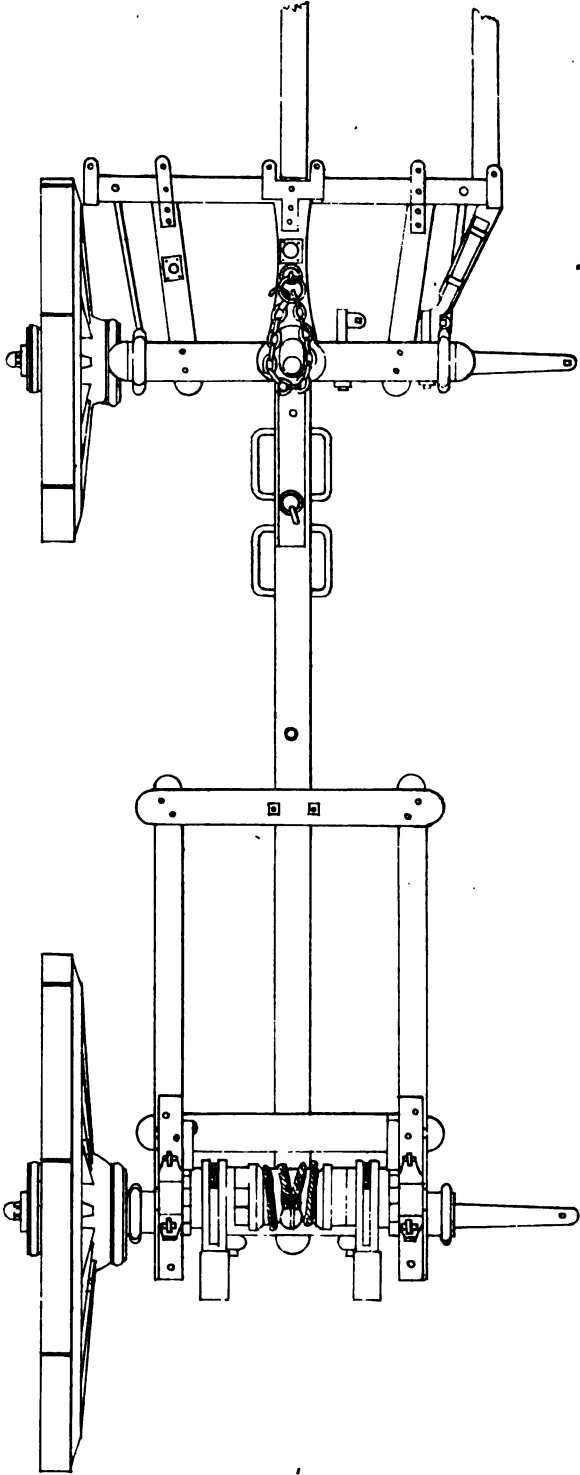
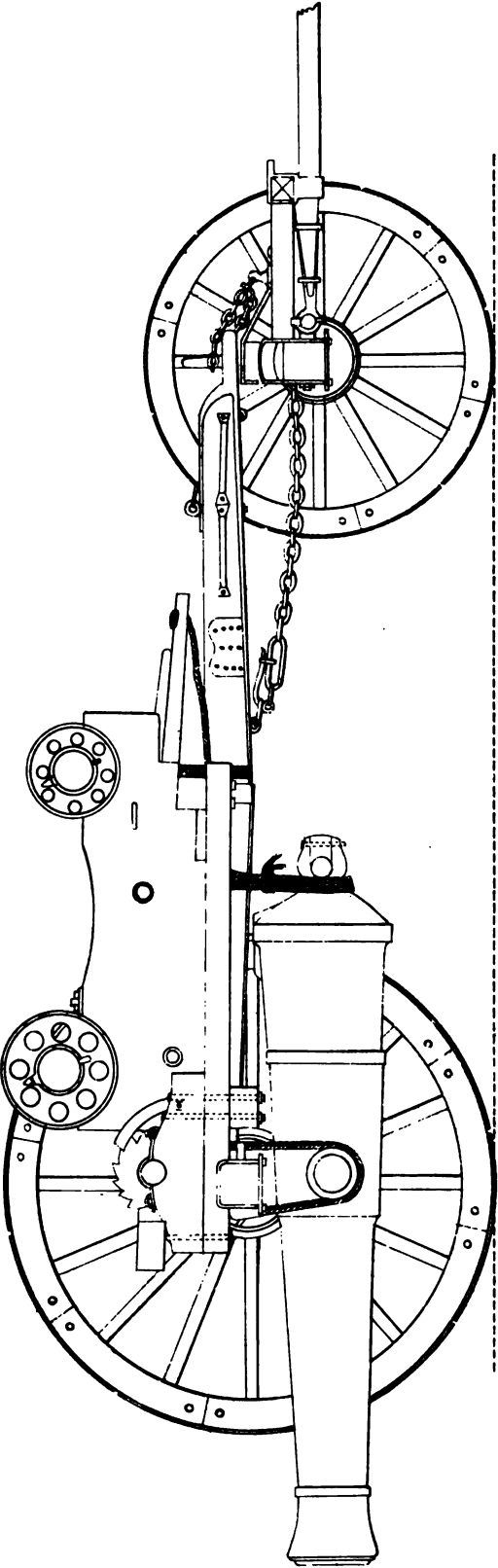
*Scale.  $\frac{3}{8}$  Inch to 1 Foot.*

*Lithographed at the Royal Artillery Institution.*

*Drawn by Serjt Inglis R.d.*



*Sling Waggon.*



*Scale.  $\frac{3}{8}$  Inch to 1 Foot.*

*Lithographed at the Royal Artillery Institution.*

*Drawn by Serjt Inglis R.A.*







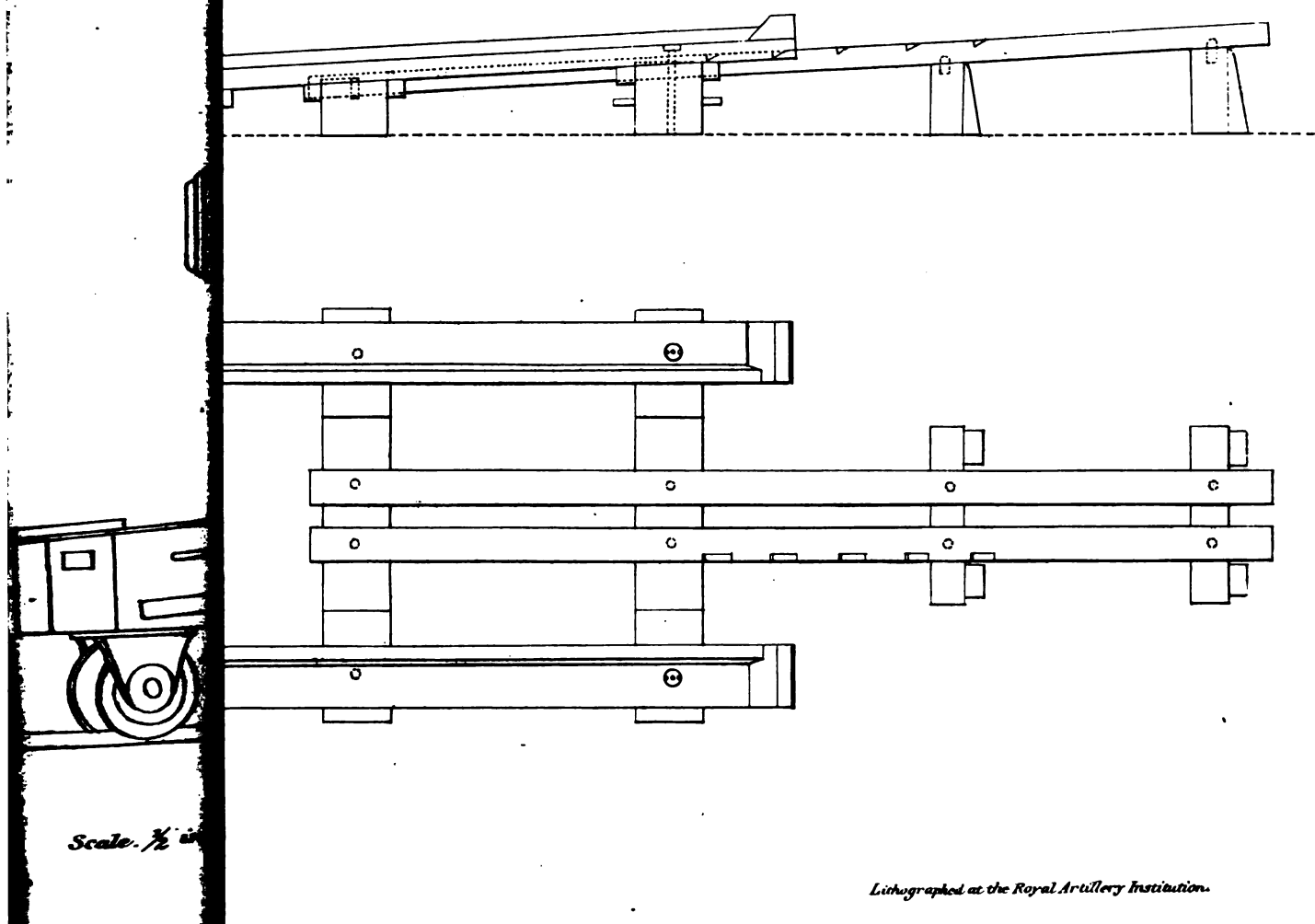


*Madras Platform.*

*For 18 P. 42 Cwt. 2 Qrs. 12 lbs.*

*Weight 14 Cwt. 2 Qrs. 12 lbs.*

*Fig. 2.*



*Lithographed at the Royal Artillery Institution.*

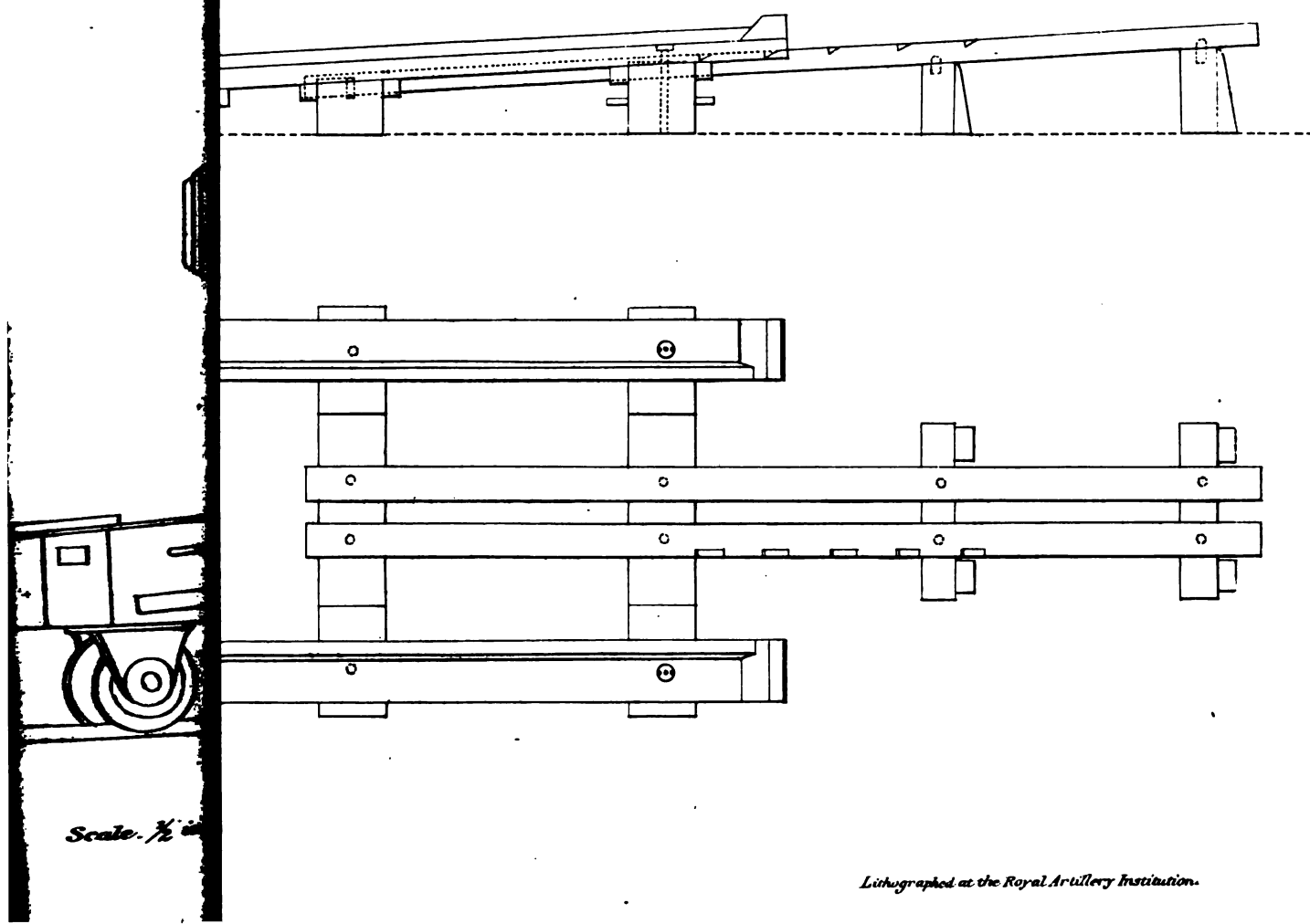


*Madras Platform.*

*For 18 P. 42 Cwt. 2 Qrs. 12 lbs.*

*Weight 14 Cwt. 2 Qrs. 12 lbs.*

*Fig. 2.*



*Scale. 1/2 in.*

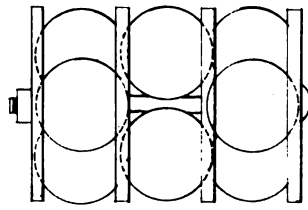
*Lithographed at the Royal Artillery Institution.*



Projectiles.

Fig. 1. Grape Shot.

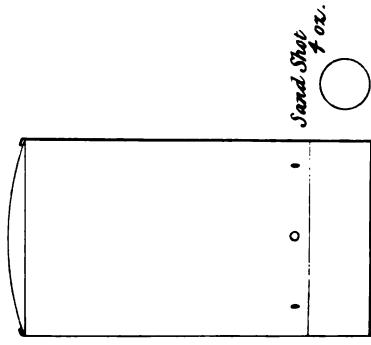
32 Pr.



6

Fig. 2. Case Shot.

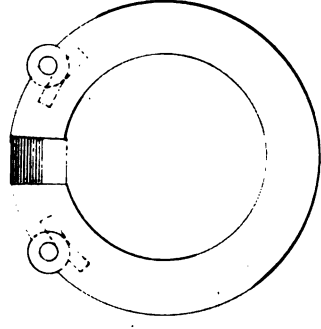
32 Pr.



6

Fig. 3. Mortar Shell.

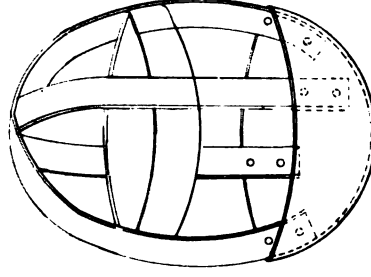
10 Inch.



6

Fig. 5. Skeleton of Ground Light Ball.

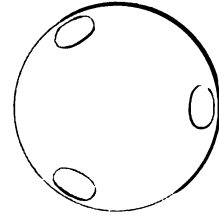
5 1/2 Inch.



6

Fig. 4. Carcass.

4 3/8 Inch.



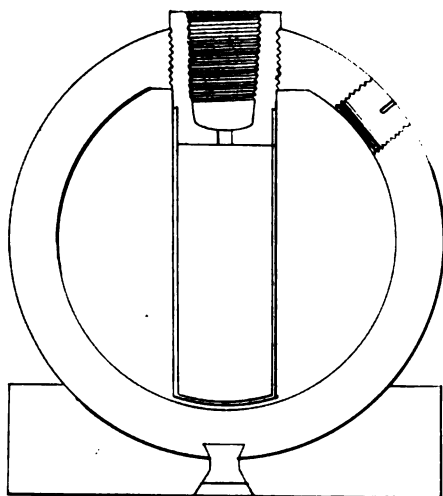
6



Projectiles.  
(with Sabots.)

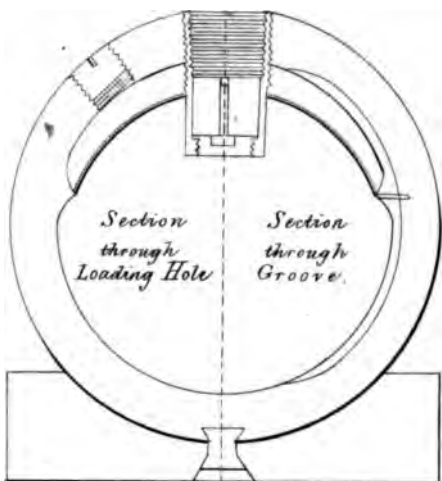
Improved Shrapnel.

32 P<sup>r</sup>



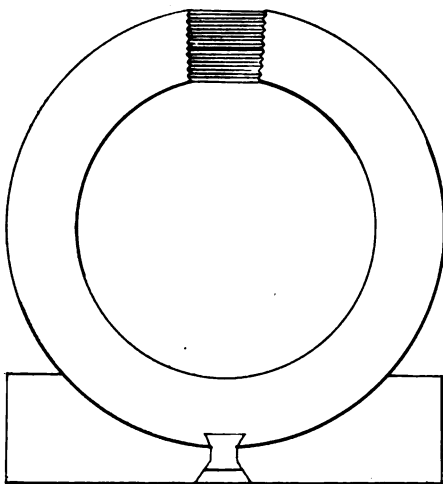
Diaphragm Shrapnel.

32 P<sup>r</sup>



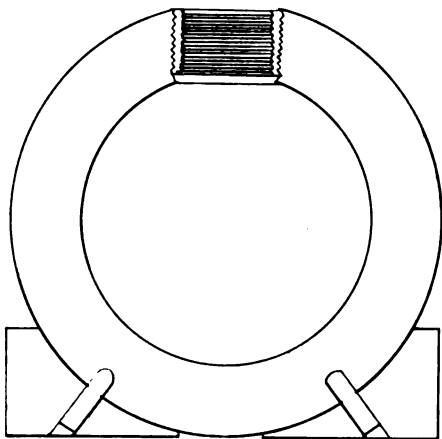
Common Shell.

32 P<sup>r</sup>



Naval Shell.

32 P<sup>r</sup>



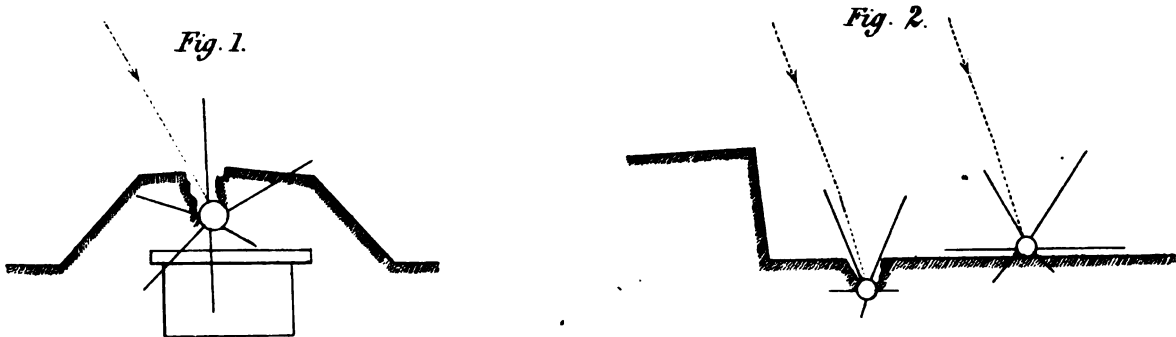
Scale 4

Lithographed at the Royal Artillery Institution.

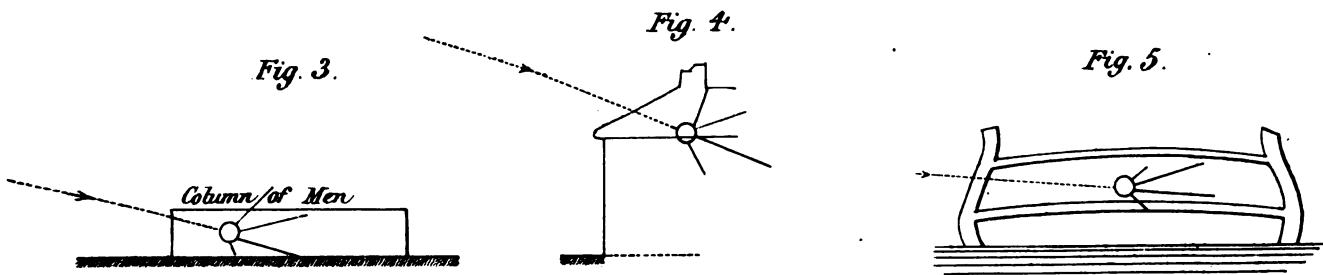




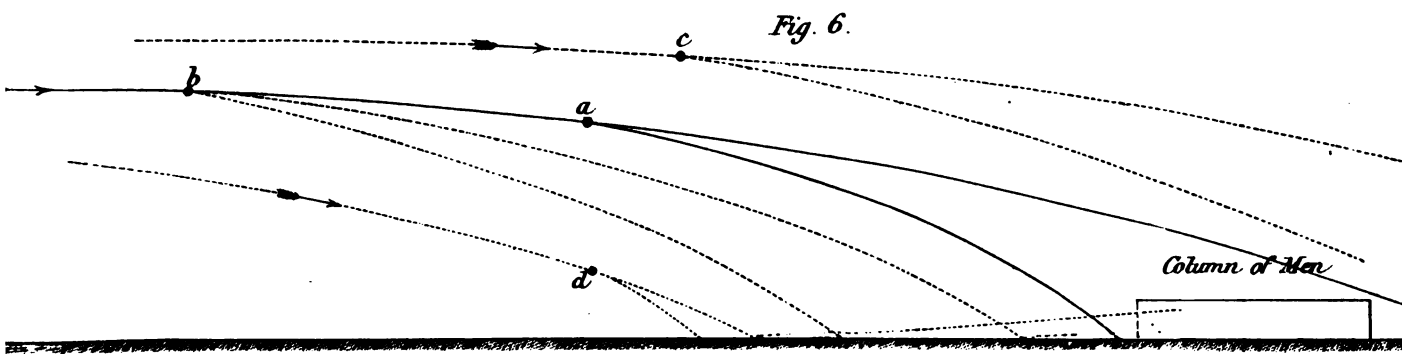
Vertical Shell Firing.



Horizontal Shell Firing.



Shrapnel Shell Firing.



*a*,..... represents the bursting of the Shell when the Fuse is good and elevation correct.  
*b*,..... short.....  
*c*,..... good but..... high.....  
*d*,..... do..... low.....



Fig. 1.

Boxer's Shrapnel.

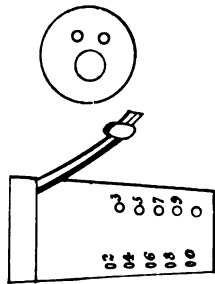


Fig. 2.

Boxer's Naval.

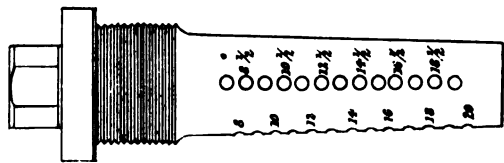


Fig. 3.

Freeburn's Concussion.

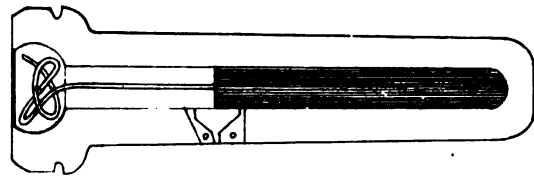


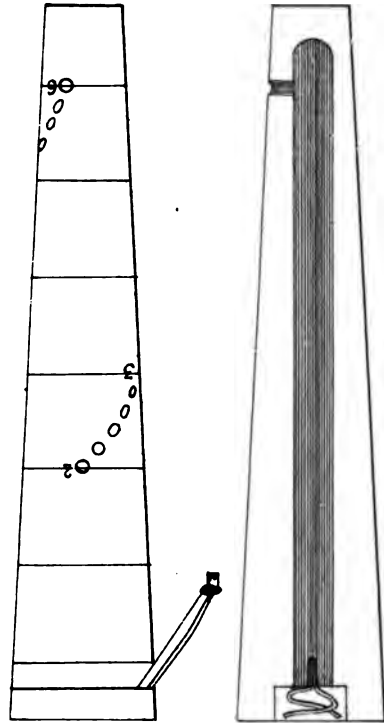
Fig. 4.

Moorsom's Percussion.



Fig. 5.

Boxer's Mortar.



Scale. One half.

Drawn by Serjt Inglis, R.A.

Lithographed at the Royal Artillery Institution.



FUZES.

Bormann's.

Fig. 1. Plan.



Fig. 2. Horizontal Section.

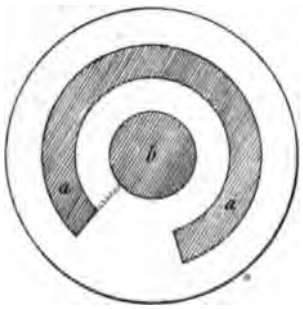
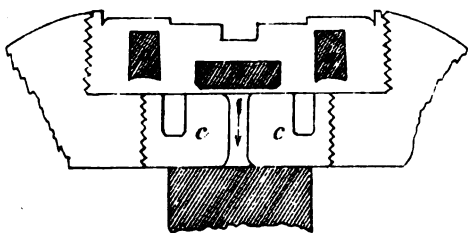


Fig. 3. Vertical Section.



Breithaupt's.

Fig. 4. Plan of Fuze.

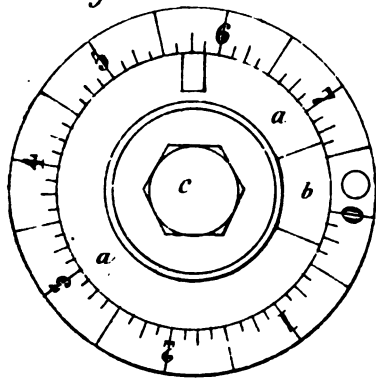


Fig. 5. Plan of Disc.

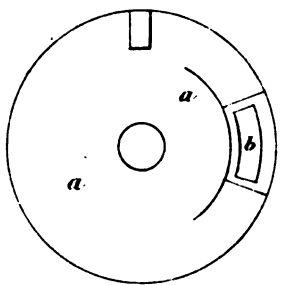
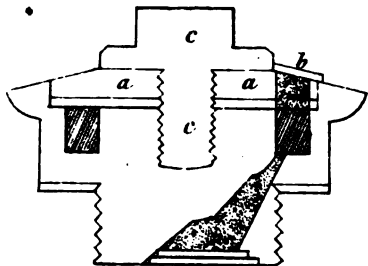


Fig. 6. Section of Fuze.



Full size.

Lithographed at the Royal Artillery Institution.



Fig. 1. Common or Quill.

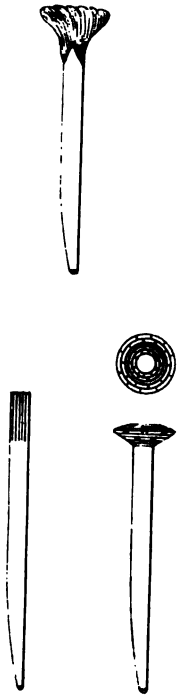


Fig. 2. Dutch or Paper.



Fig. 3. Common Metal.

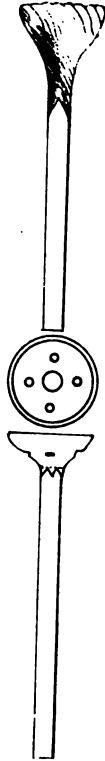


Fig. 4. Detonating Quill.



Fig. 5. Metal Friction.

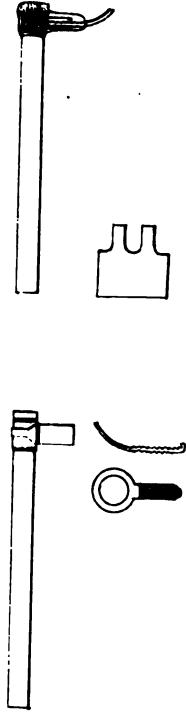


Fig. 6. Quill Friction.

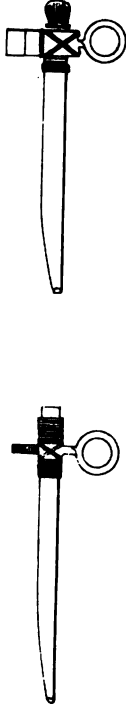


Fig. 7. Galvanic.



Scale: One half.

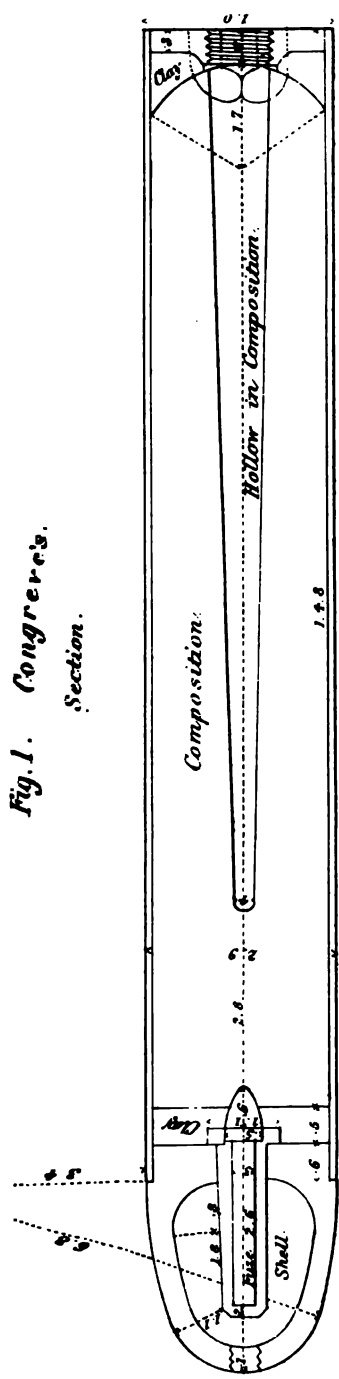
Lithographed at the Royal Arsenal, Toulon.

Drawn by Sgts. Hughes R.A.





Fig. 1. Congreve's.  
Section.



Socket Fig. 2 Stick

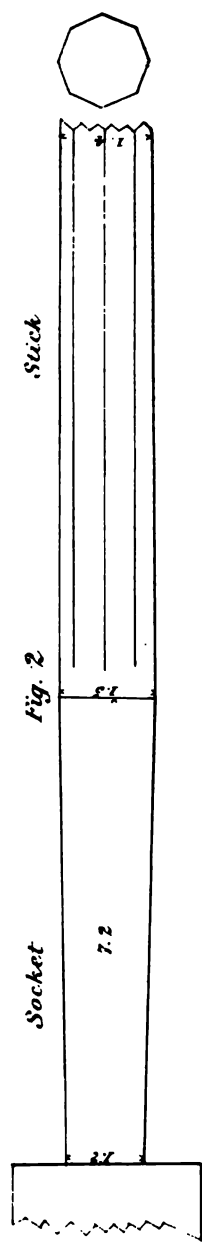


Fig. 3. Carcass head.

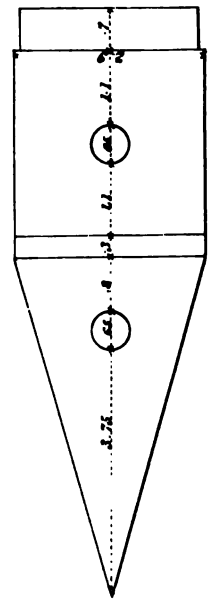


Fig. 4. Bottom Plate.

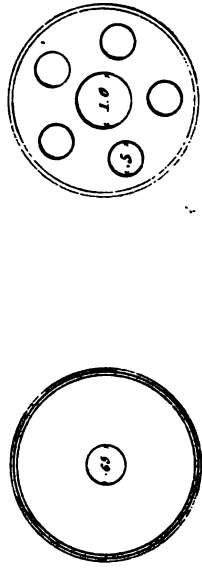
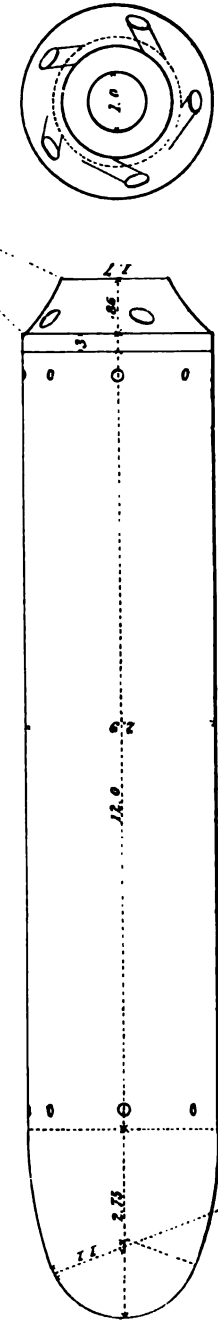


Fig. 5. Hale's



Scale. 1/3"



Fig. 1.

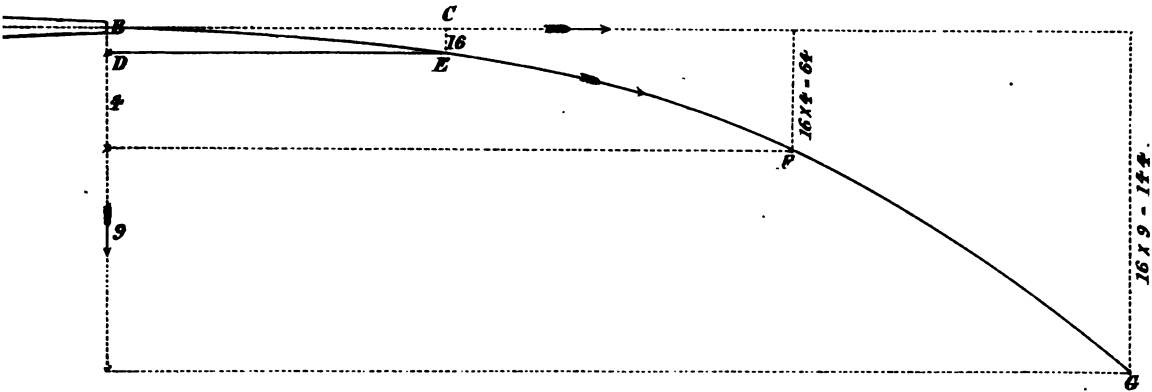


Fig. 2.

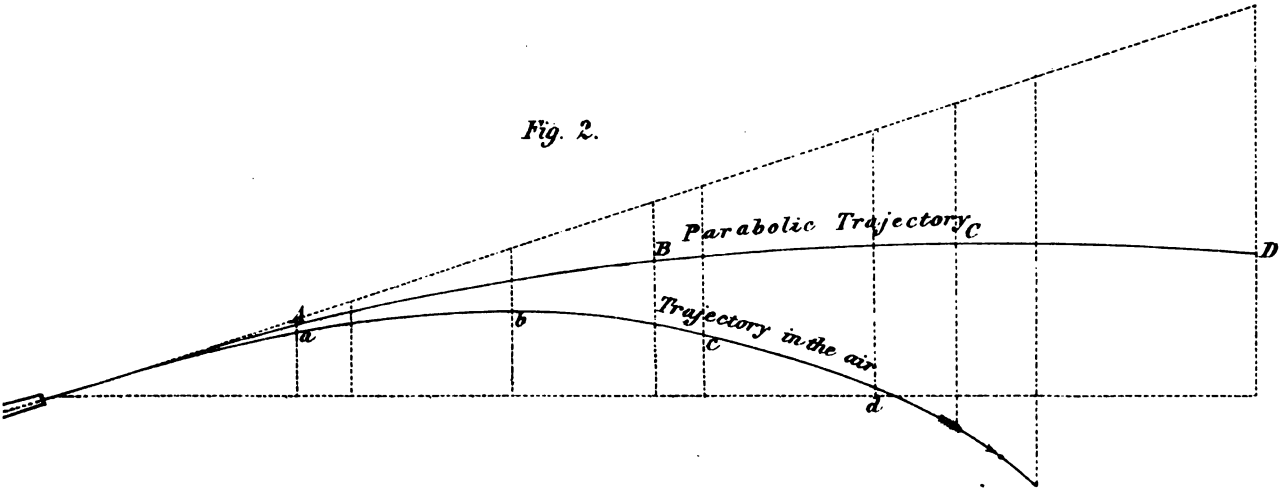
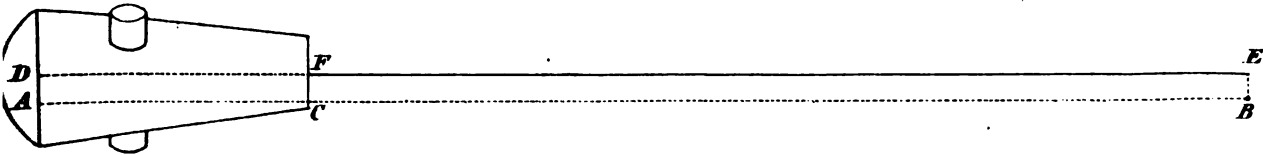


Fig. 3.



Fig. 4.





6 feet from Ground

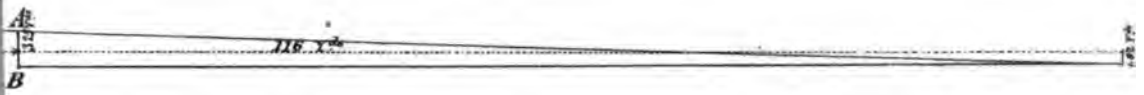
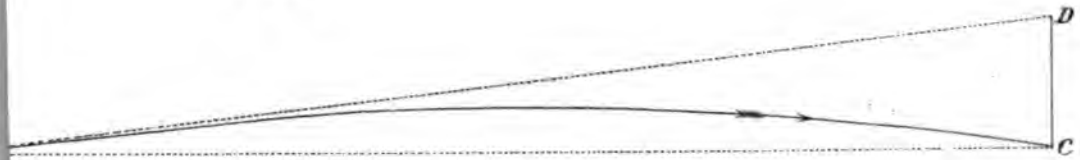


Fig. 4.



Electro-Ballistic Apparatus.

Fig. 8.

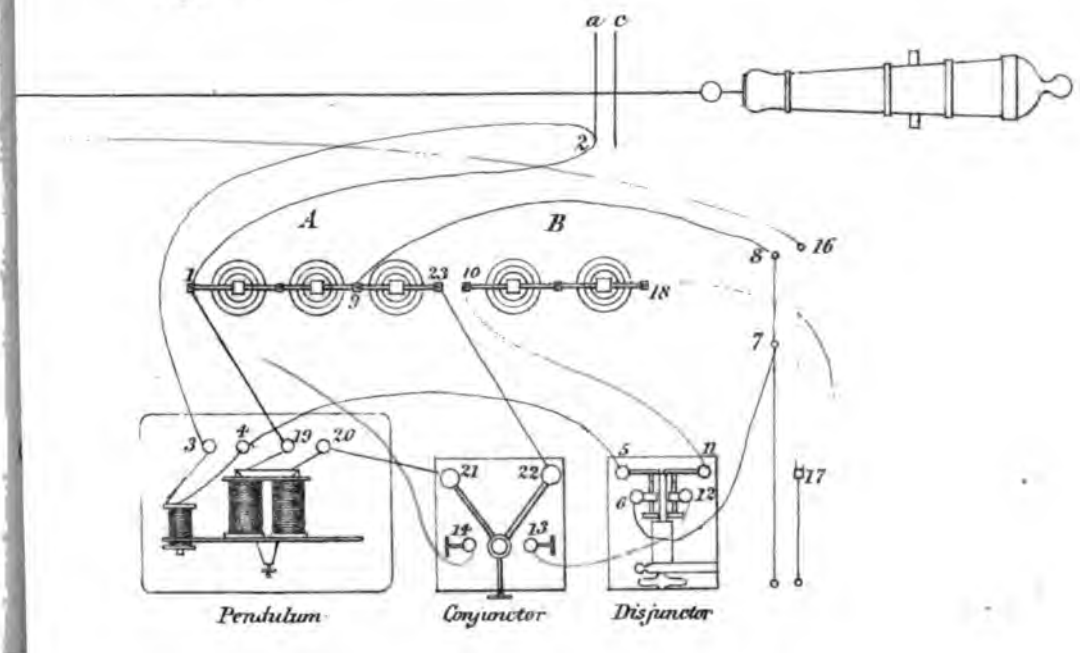




Fig. 1.

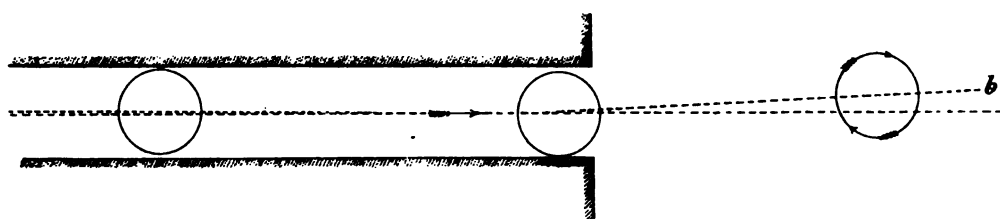


Fig. 2.

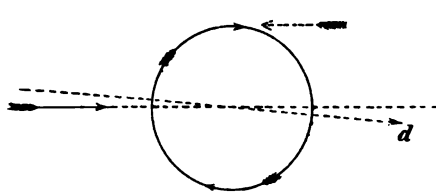


Fig. 3.

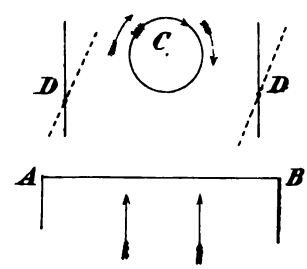


Fig. 4.

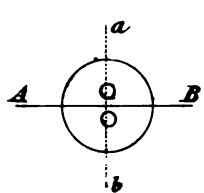


Fig. 5.

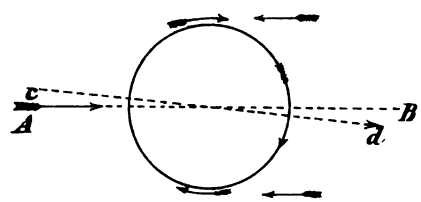


Fig. 6.

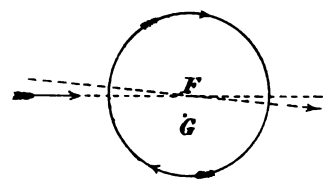


Fig. 7.

(Eccentric Shot)

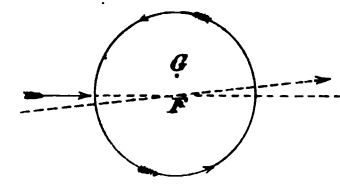


Fig. 8.

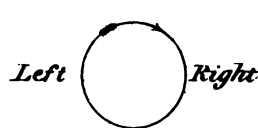


Fig. 9.

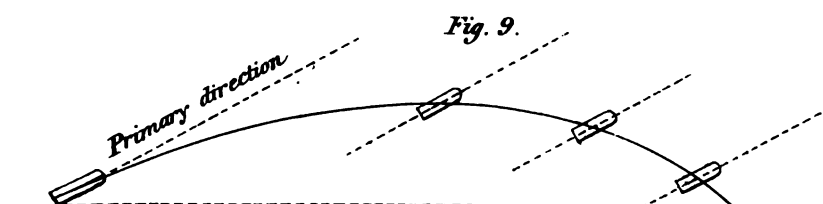


Fig. 10.



Fig. 11.

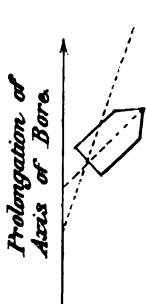


Fig. 12.

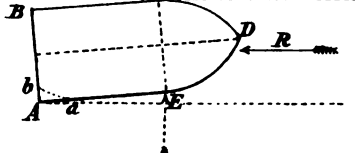


Fig. 13.

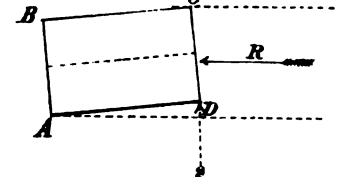


Fig. 14.

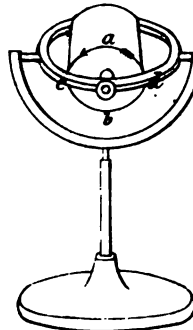
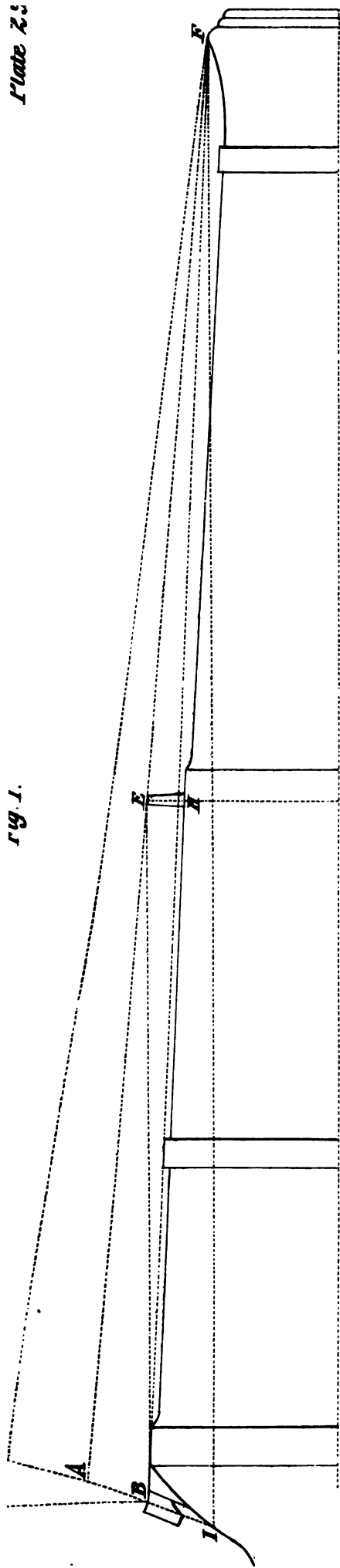








Fig. 1.



*A, E, B, is the Clearance Angle which differs with the form of the piece, When the top of the Tangent Scale is raised to the Clearance angle, it, (A) the top of the Middle-sight (E) & Muzzle notch (B) are in line.*

*BE, - r.  
BF, - R.  
DB, C. a.*

Fig. 2.

*Spirit Level Quadrant.*

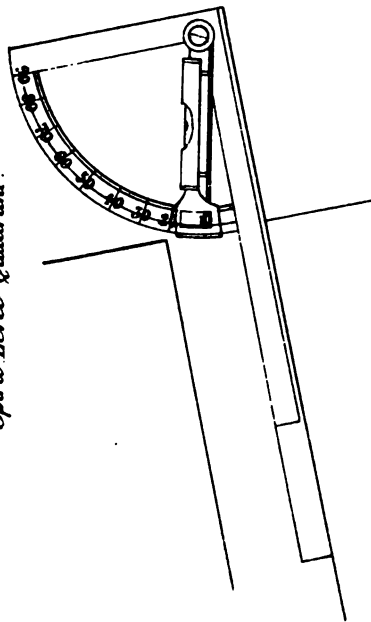


Fig. 3.

*Gunner's Quadrant.*

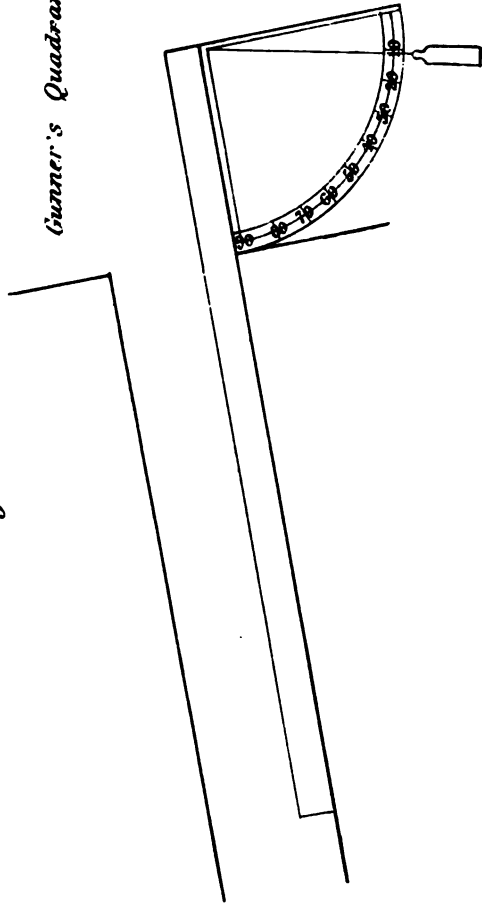




Fig. 1.

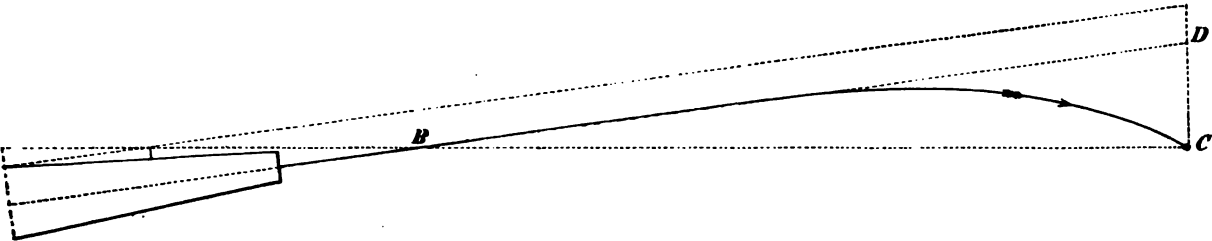


Fig. 2.  
Ricochet Fire.

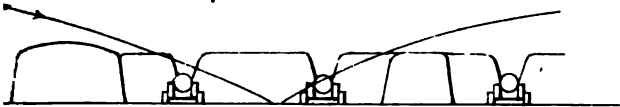
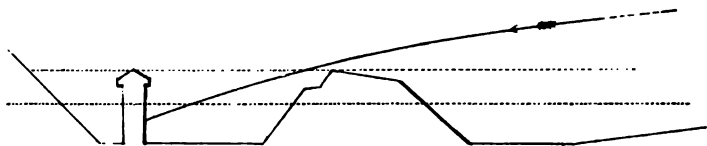


Fig. 3.  
Curved Fire.



Vertical Fire.

Fig. 4.

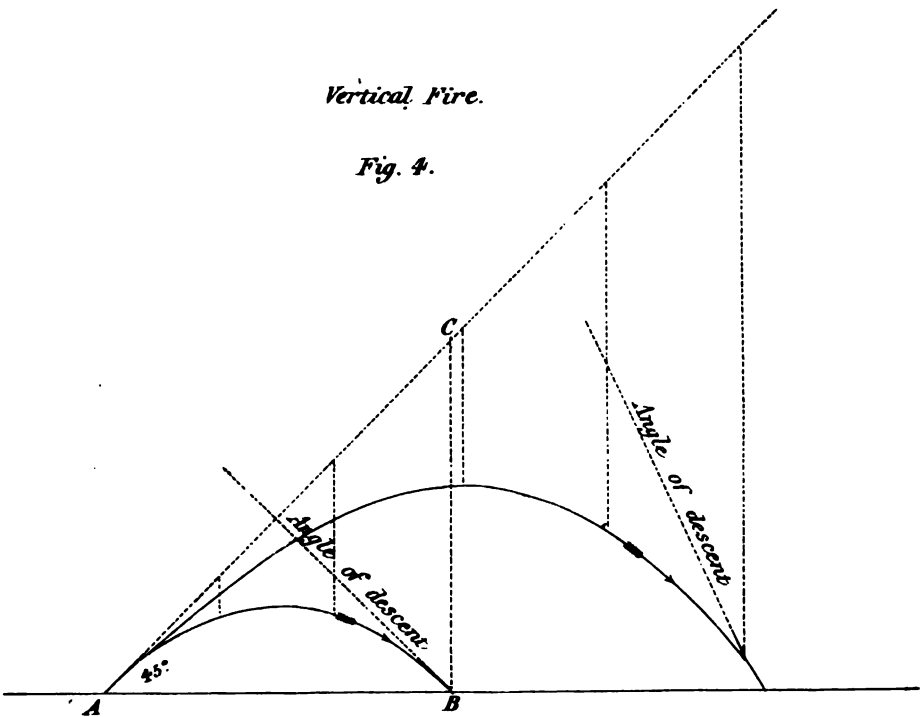
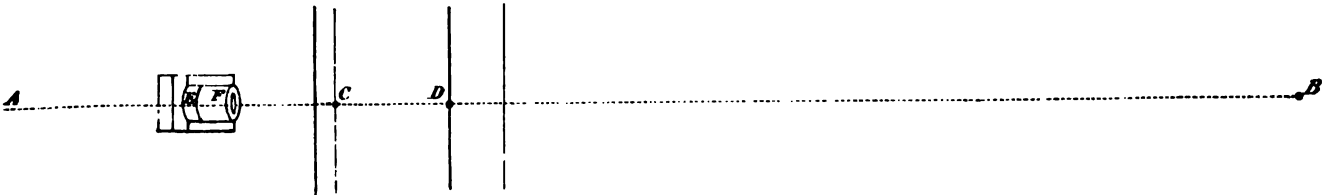


Fig. 5.





*Bullets.*

Fig. 1.

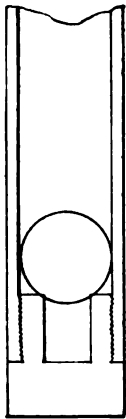


Fig. 2.

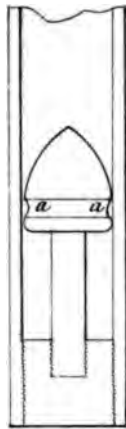
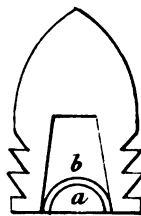


Fig. 3.

*Minie.*



*a, is the Iron Cup  
b, is the hollow in the Bullet*

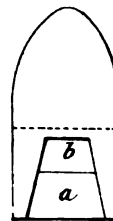
Fig. 4.

*Pritchett.*



Fig. 5.

*Service.*



*a, is the Boxwood Plug  
b, is the hollow in the Bullet*

Fig. 6.  
*Jacob.*

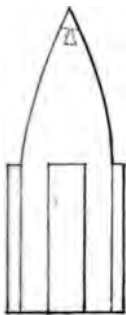


Fig. 7.  
*Wilkinson.*

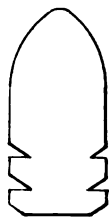
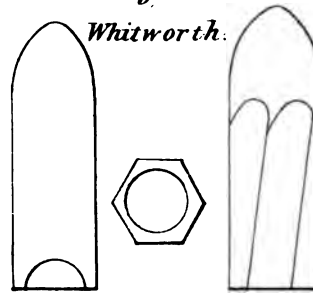


Fig. 8.  
*Langcaster*



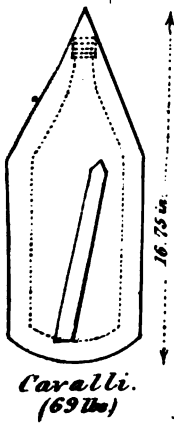
Fig. 9.

*Whitworth.*



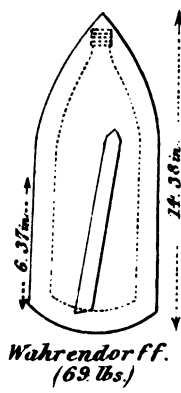
*Projectiles for Rifled Ordnance.*

Fig. 10.



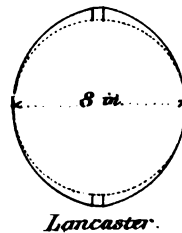
*Caralli.  
(69 lbs)*

Fig. 11.



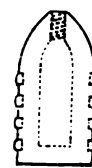
*Wahrendorff.  
(69 lbs.)*

Fig. 12.



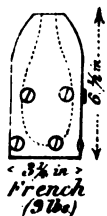
*Lancaster.*

Fig. 16



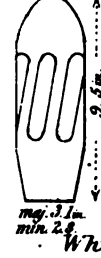
*Prussian  
(13 lbs)*

Fig. 13.



*3 1/2 in.  
French  
(9 lbs)*

Fig. 14

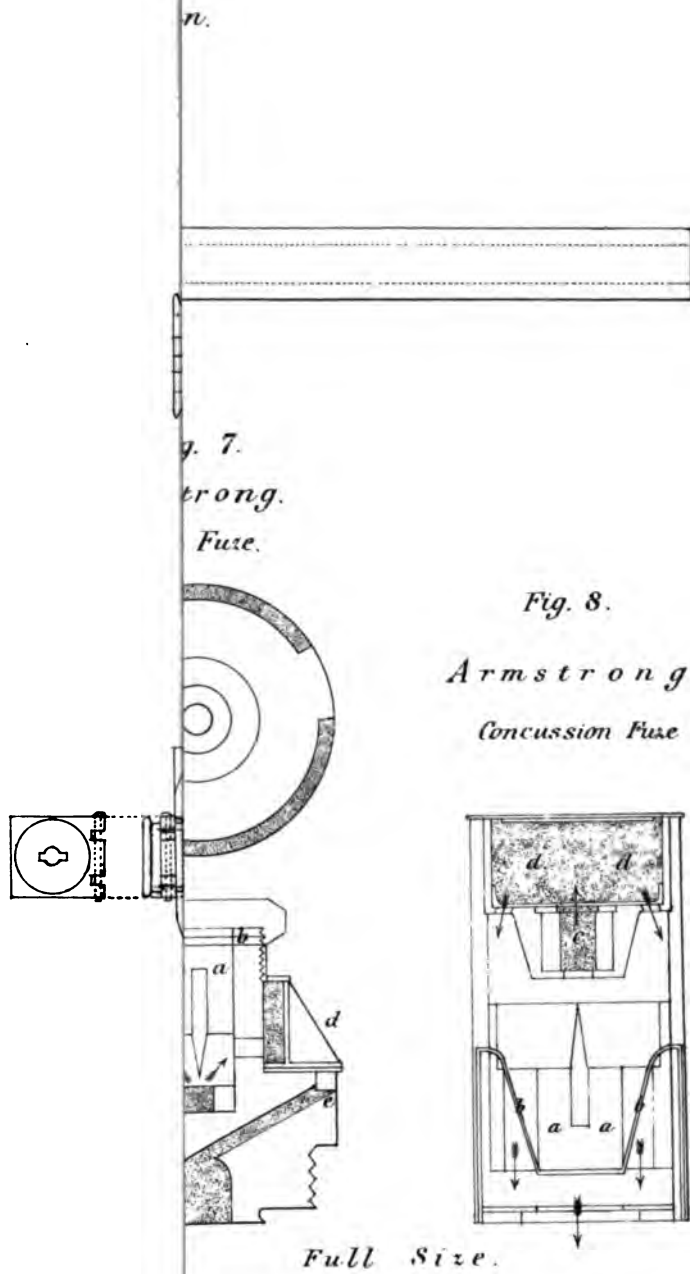


*mag. 3 1/2 in.  
min. 2 1/2  
Whitworth. (12 lbs)*

Fig. 15.







|                   |                           |
|-------------------|---------------------------|
| nts the Hammer    | a a, Hammer.              |
| Suspending Pin    | b b, Suspending Pin.      |
| Detonating Comp?  | c, Detonating Composition |
| Hollow Collar.    | d d, Priming Chamber.     |
| Fuse Composition. |                           |

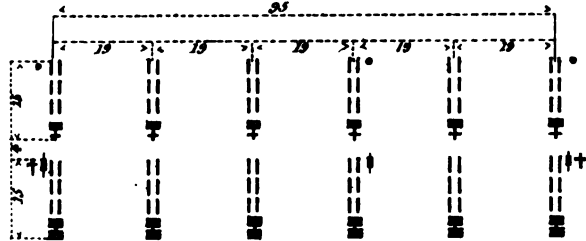




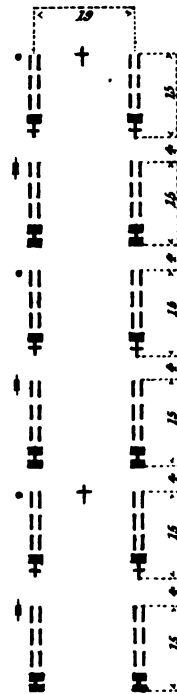
*Formations of a Battery or Brigade of Batteries.*

*(Shewing ground occupied in each)*

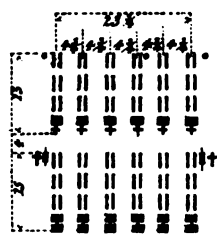
*Battery in Line full intervals.*



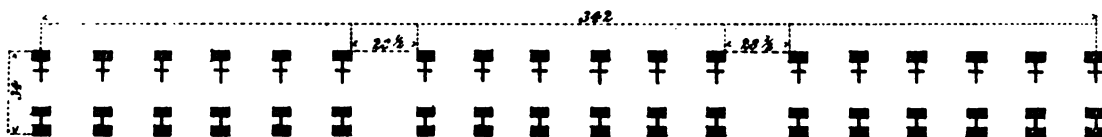
*Battery in Column of Divisions.*



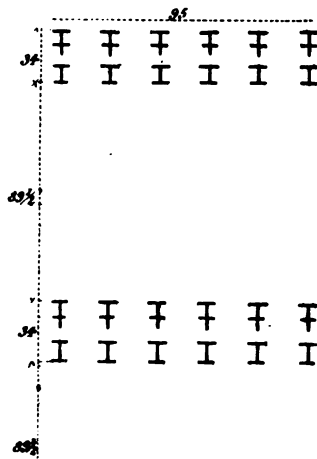
*Battery in Line  $\frac{1}{2}$  intervals*



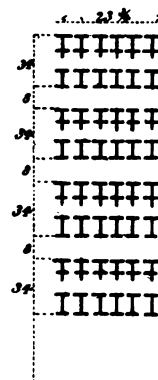
*Brigade of Batteries in Line full intervals.*



*Open Column of Batteries full intervals.*



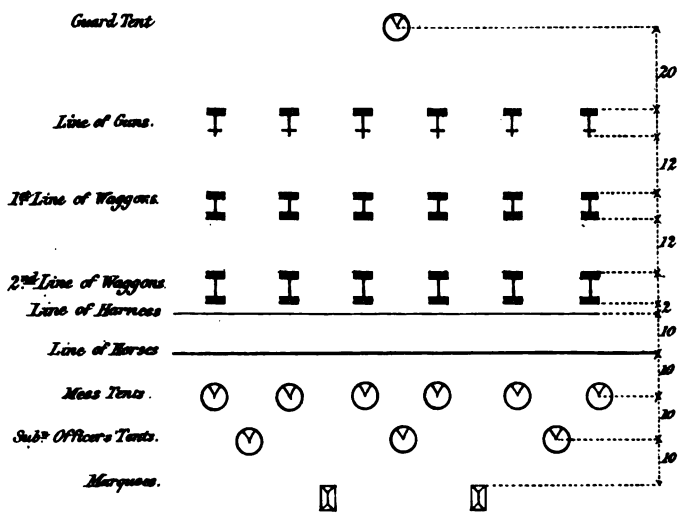
*Close Column of Batteries  $\frac{1}{2}$  intervals.*



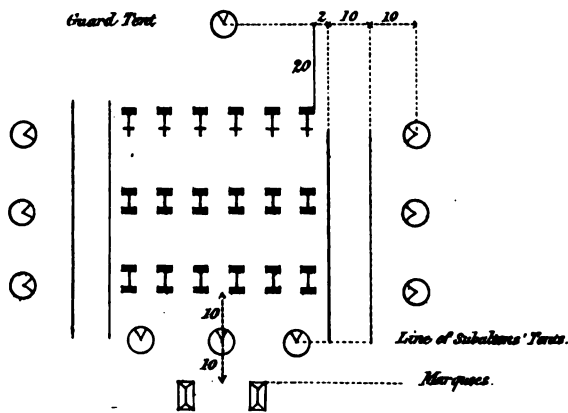


Encampment of a Field Battery.

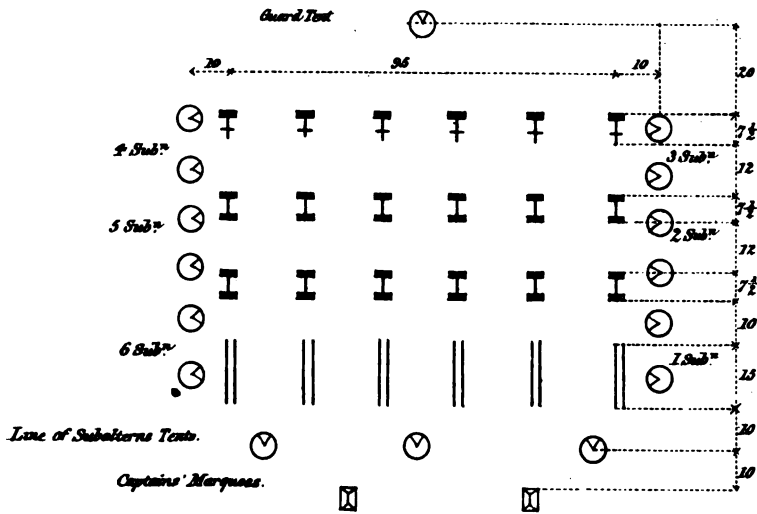
First Method.

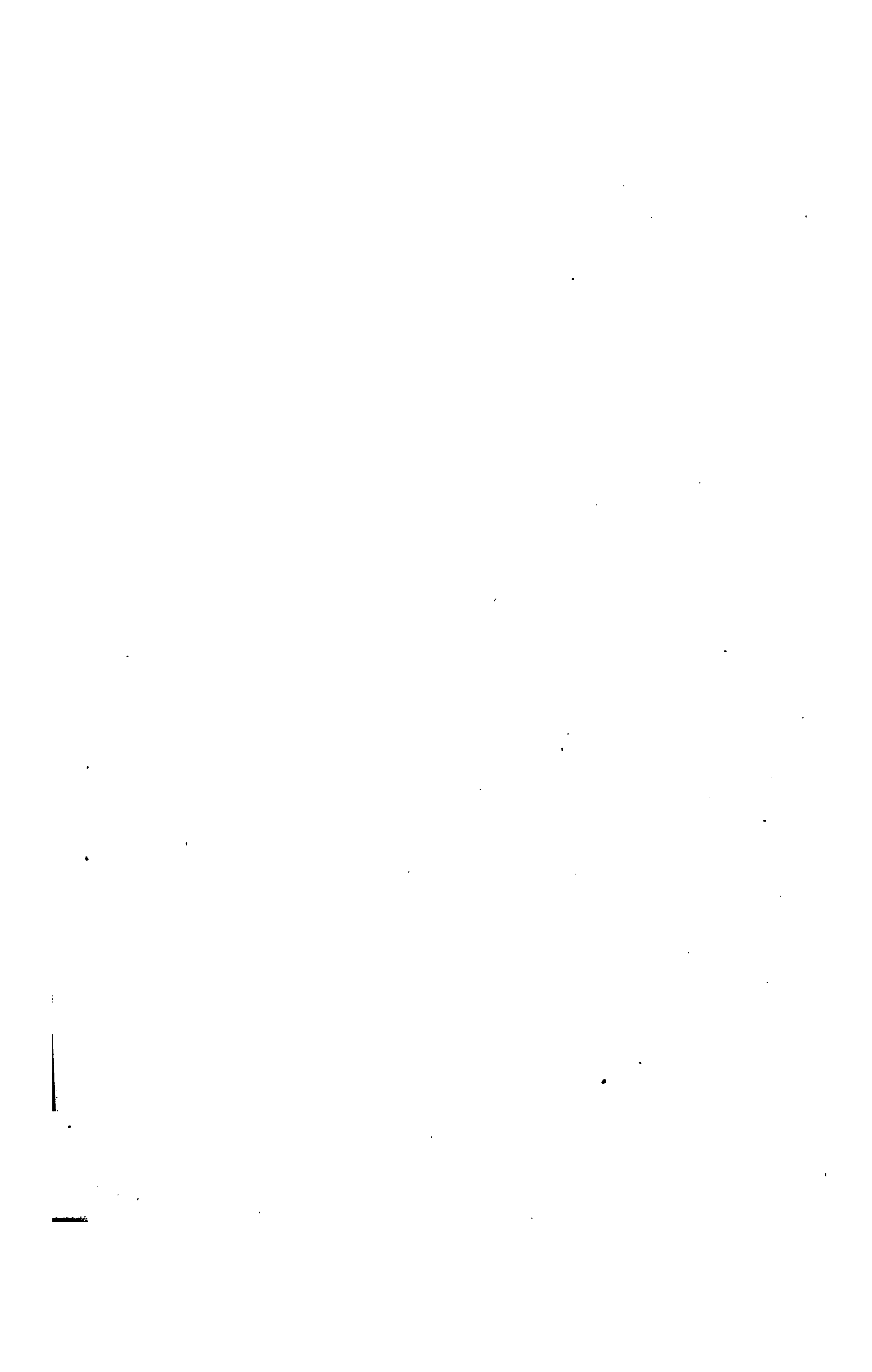


Second Method.

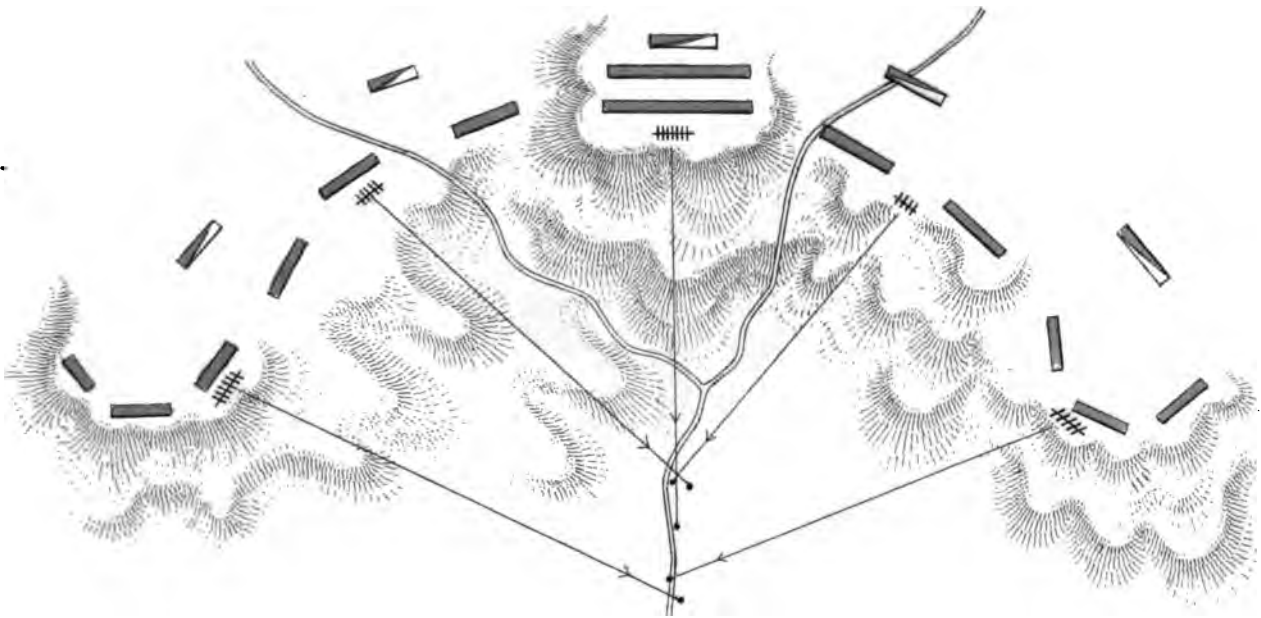


Third Method.

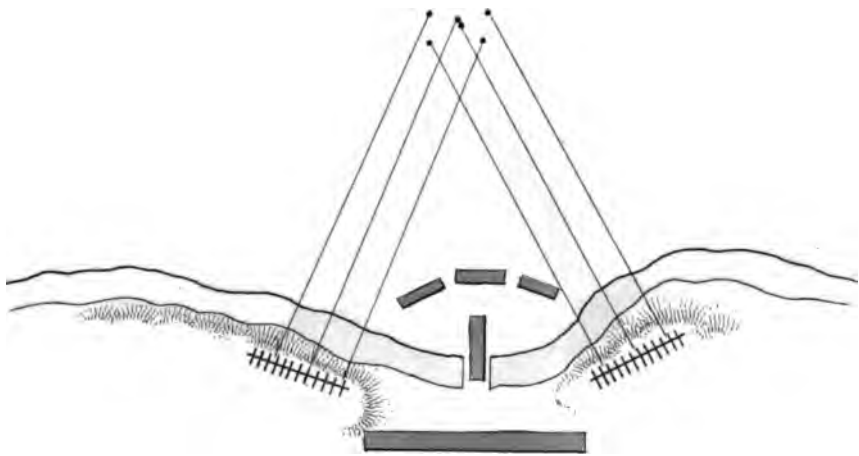




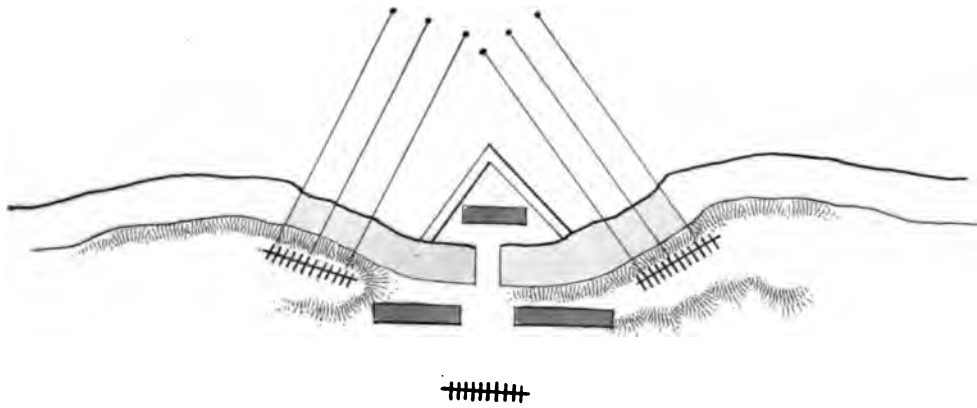
*Fig. 1. Artillery defence of a good Position.*



*Fig. 2. Artillery assisting in the passage of a river.*



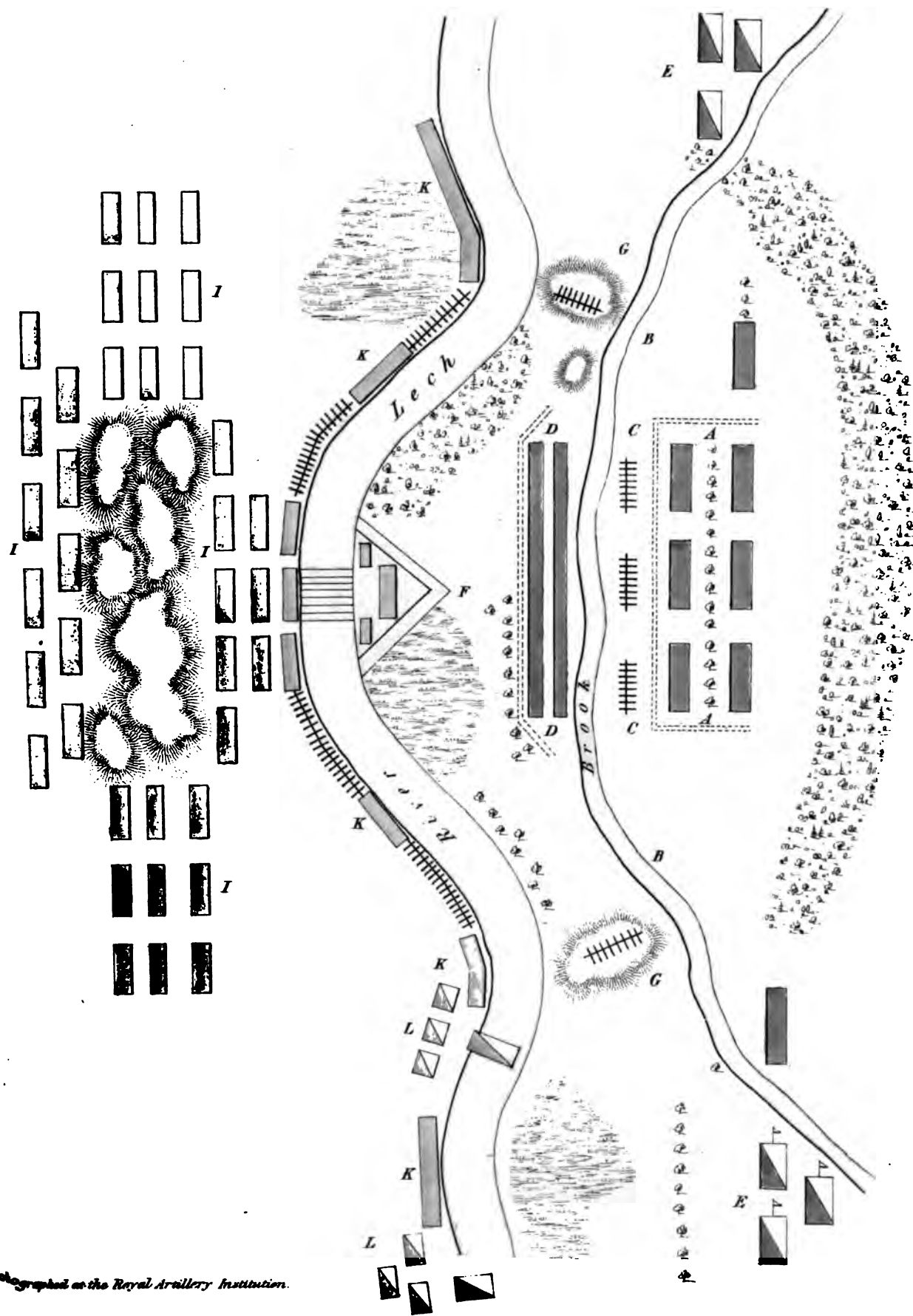
*Fig. 3. Artillery defending the passage of a River.*





PASSAGE OF THE LECH IN 1632.

Plate 36.

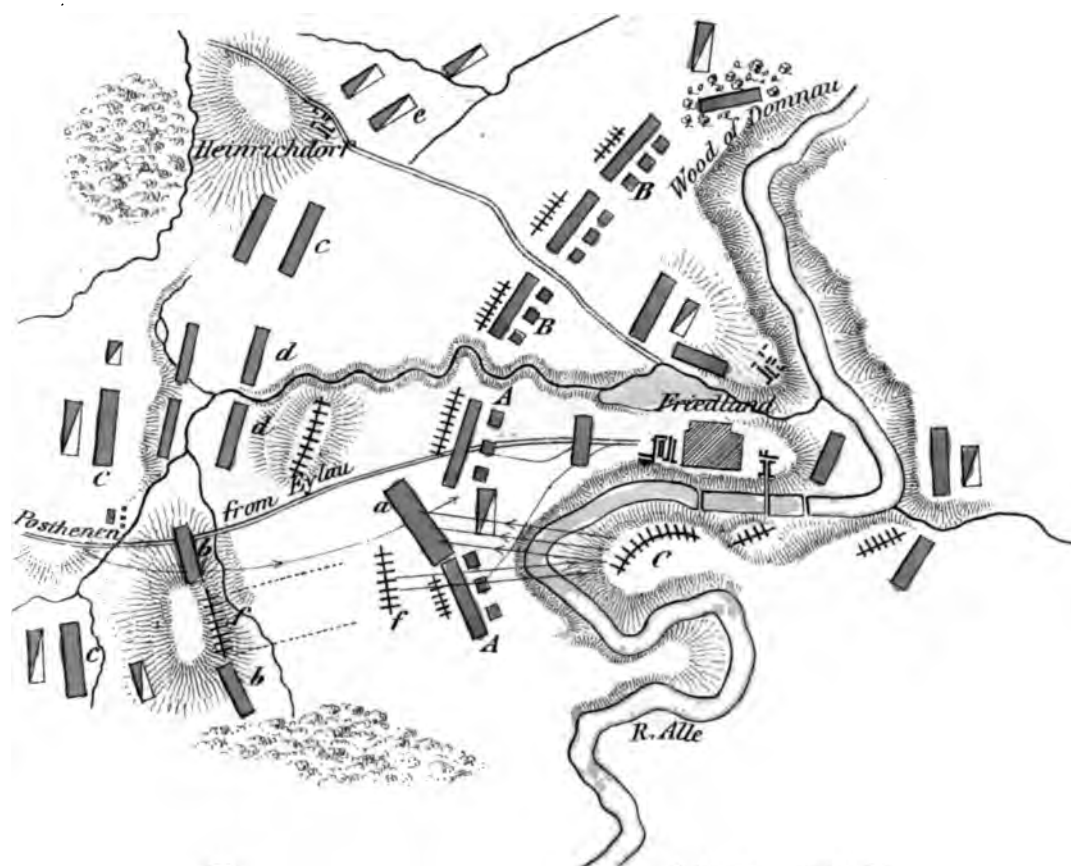


Lithographed at the Royal Artillery Institution.





**BATTLE OF FRIEDLAND, 14<sup>TH</sup> JUNE, 1807.**



*a. Ney.*

*b. Victor.*

*c. Guard I.*

*d. Lannes.*

*e. Mortier.*

*f. Battery advanced by Senarmont.  
to assist Ney.*

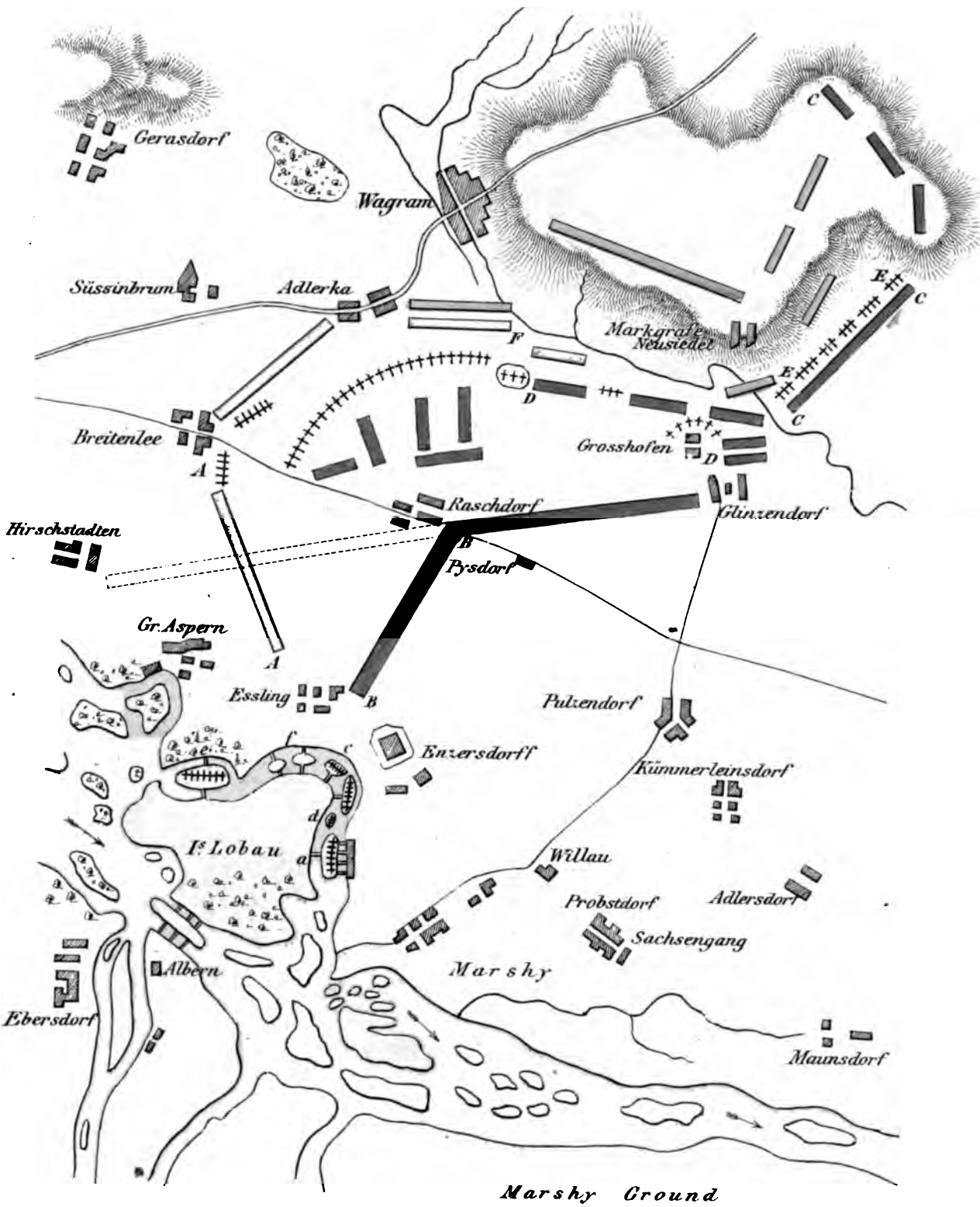
*AA. Gortchakoff.*

*BB. Bagrathion.*

*C. Battery which took  
Ney in flank.*



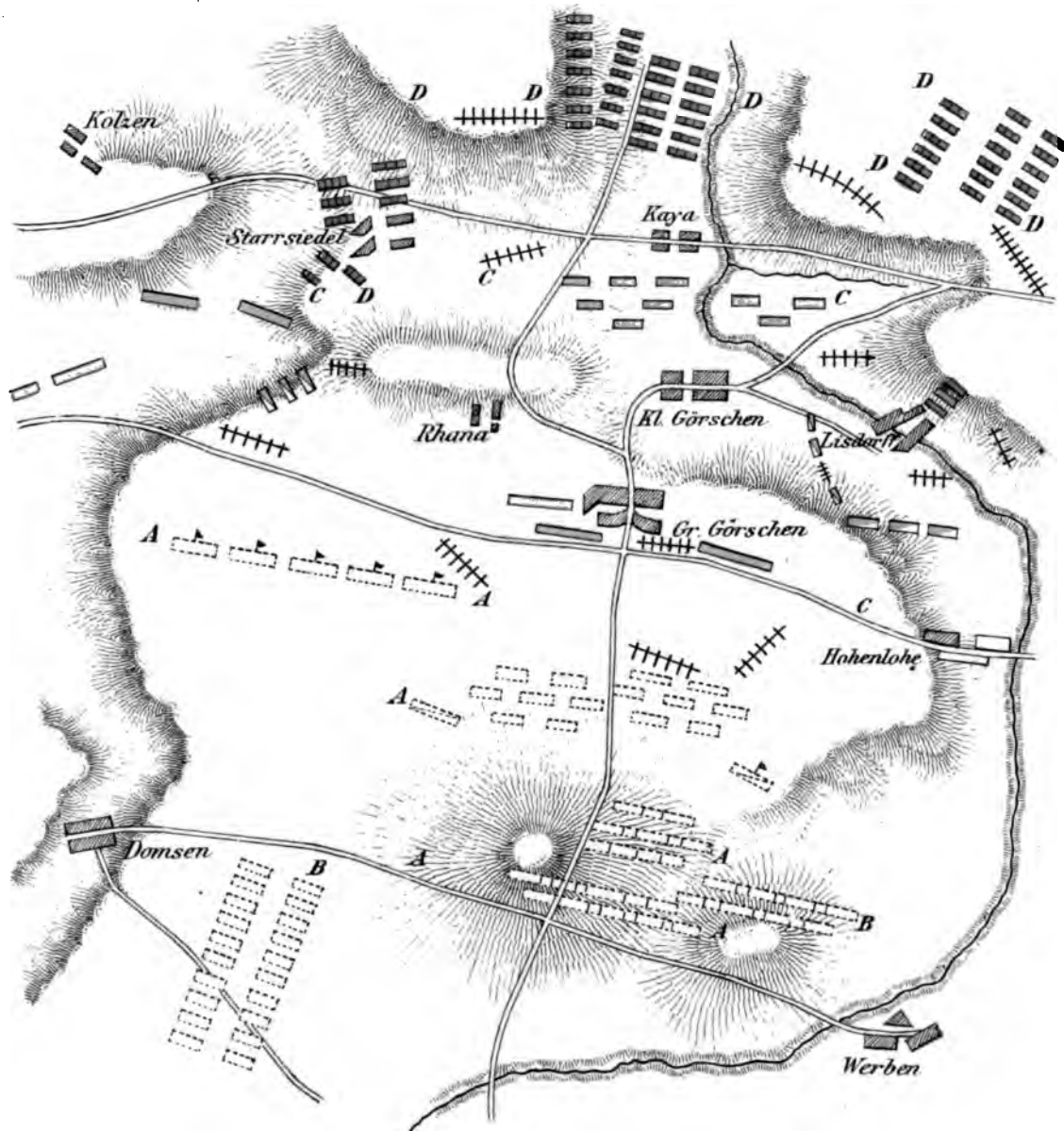
BATTLE OF WAGRAM, 6<sup>TH</sup> JULY, 1809.



Lithographed at the Royal Artillery Institute

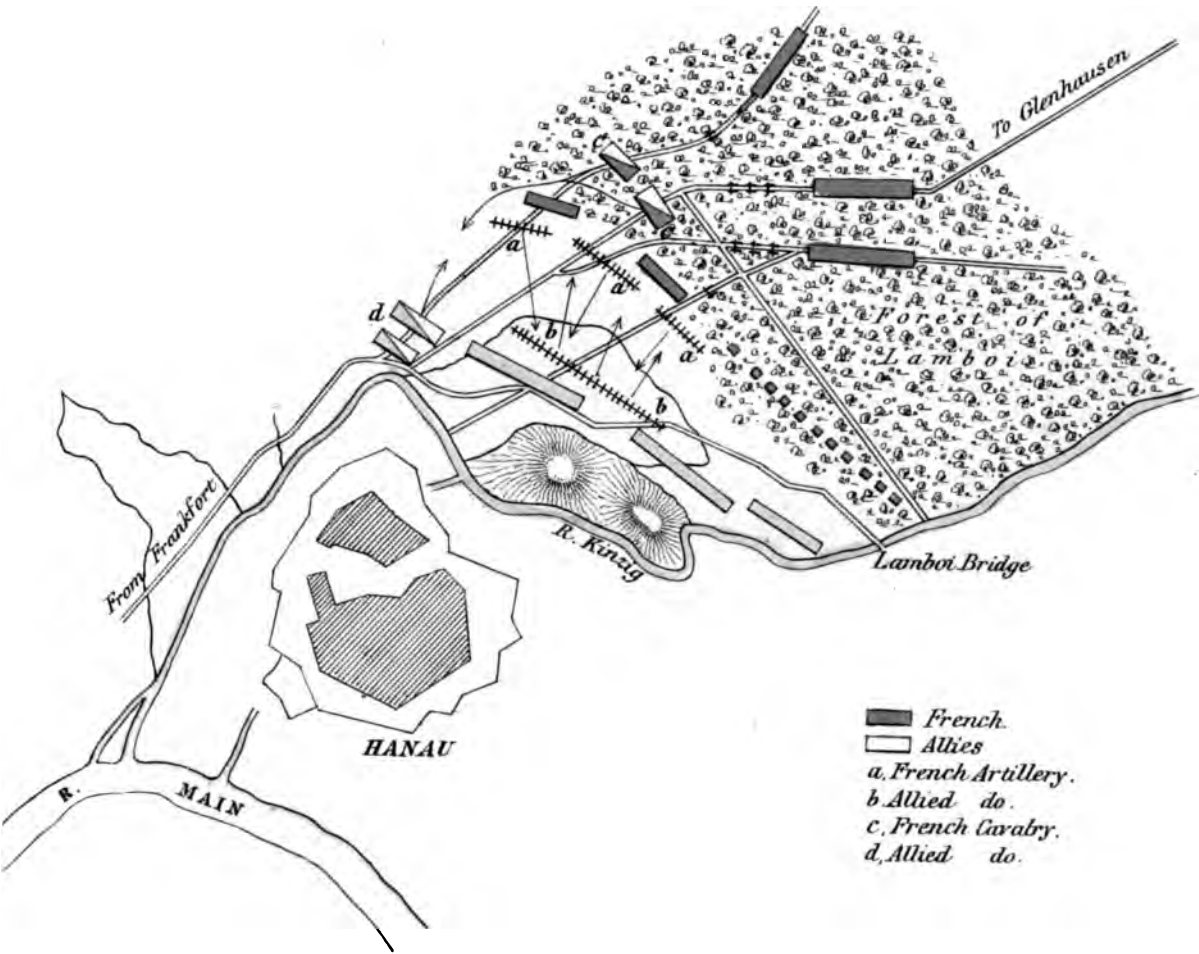


**BATTLE OF LUTZEN, 2<sup>ND</sup> MAY, 1813.**





**BATTLE OF HANAU. 30<sup>th</sup> OCT. 1813.**



*Lithographed at the Royal Artillery Institution.*





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